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Well CdV-R-15-3 Completion Report

Los Alamos NATIONAL LABORATORY

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Cover photo shows a modified Foremost Dual Rotary (DR-24) drill rig. The DR-24 is one of several drill-rig types being used for drilling, well installation, and well development in support of the Los Alamos National Laboratory Hydrogeologic Workplan. The Hydrogeologic Workplan is jointly funded by the Environmental Restoration Project and Defense Programs to characterize groundwater flow beneath the 43-square-mile area of the Laboratory and to assess the impact of Laboratory activities on groundwater quality. The centerpiece of the "Hydrogeologic Workplan" is the installation of up to 32 deep wells in the regional aquifer.

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Well CdV-R-15-3 Completion Report

Bill Kopp
*Andy Crowder**
*Mark Everett**
David Vaniman
Donald Hickmott
William Stone
*Ned Clayton***
Steve Pearson
*Dave Larssen****

**Washington Group International, Inc., 2237 Trinity Dr., Los Alamos, NM 87544*
***SchlumbergerSema Utilities, 6399 S. Fiddler's Green, Greenwood Village, CO 80111*
****Westbay Instruments, Inc., 115-949 West Third St., North Vancouver, BC V7P 3P7 Canada*

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List of Acronyms and Abbreviations

AI	array induction
AITH	array induction tool, version H
API	American Petroleum Institute
APS	accelerator porosity sonde
ASTM	American Society for Testing and Materials
bgs	below ground surface
BV	borehole video
BGO	bismuth germanate
CMR	combinable magnetic resonance
CMS	corrective measures study
cps	counts per second
cu	capture unit
DEV	deviation
DOE	Department of Energy (U.S.)
DR	dual rotary
ELAN	Elemental Log Analysis (software)
EPA	Environmental Protection Agency (U.S.)
ER	environmental restoration
FBS	full bore spinner
FIP	field implementation plan
FMI	formation microimager
FSF	Field Support Facility (ER Project)
GFAA	graphite furnace atomic absorption
GPIT	general purpose inclinometer tool
GR	gamma ray
HE	high explosives
HI	hydrogen index
HNGS	hostile environment gamma-ray sonde
HPLC	high-performance liquid chromatography
HSA	hollow-stem auger
ICPES	inductively coupled plasma emission spectroscopy
IRMS	isotope ratio mass spectroscopy
JSAI	John Shoemaker and Associates, Incorporated
LOI	loss on ignition
NGR	natural gamma ray
NGS	natural gamma-ray spectrum
NMR	nuclear magnetic resonance
NTU	nephelometric turbidity unit
OD	outside diameter
Pe	photoelectric factor
PI	principal investigator
PTS	pressure temperature sonde
QA	quality assurance
RC	reverse circulation
RPF	Records Processing Facility (ER Project)
SPIN	spinner
TA	technical area

TD	total depth
TDS	total dissolved solids
TEMP	temperature
3-D	three-dimensional
TIC	total inorganic carbon
TLD	triple lithodensity
TOC	total organic carbon
UDR	universal drill rig
WGI/PMC	Washington Group International/Program Management Company
XRF	x-ray fluorescence

Metric to English Conversions

Multiply SI (Metric) Unit	by	To Obtain US Customary Unit
kilometers (km)	0.622	miles (mi)
kilometers (km)	3281	feet (ft)
meters (m)	3.281	feet (ft)
meters (m)	39.37	inches (in.)
centimeters (cm)	0.03281	feet (ft)
centimeters (cm)	0.394	inches (in.)
millimeters (mm)	0.0394	inches (in.)
micrometers or microns (µm)	0.0000394	inches (in.)
square kilometers (km^2)	0.3861	square miles (mi^2)
hectares (ha)	2.5	acres
square meters (m^2)	10.764	square feet (ft^2)
cubic meters (m^3)	35.31	cubic feet (ft^3)
kilograms (kg)	2.2046	pounds (lb)
grams (g)	0.0353	ounces (oz)
grams per cubic centimeter (g/cm^3)	62.422	pounds per cubic foot (lb/ft^3)
milligrams per kilogram (mg/kg)	1	parts per million (ppm)
micrograms per gram (µg/g)	1	parts per million (ppm)
liters (L)	0.26	gallons (gal.)
milligrams per liter (mg/L)	1	parts per million (ppm)
degrees Celsius (°C)	9/5 + 32	degrees Fahrenheit (°F)

WELL CdV-R-15-3 COMPLETION REPORT

by

Bill Kopp, Andy Crowder, Mark Everett, David Vaniman, Donald Hickmott, William Stone, Ned Clayton, Steve Pearson, Dave Larssen

ABSTRACT

The well known as Cañon de Valle R-15-3 (CdV-R-15-3) is located east of Cañon de Valle, within Technical Area 15 (TA-15) of Los Alamos National Laboratory (the Laboratory, or LANL). CdV-R-15-3 is the first completed well (out of three planned wells) that was constructed primarily for the purpose of investigating the extent of contamination in deep perched and regional groundwater systems associated with high explosives (HE), presumed to be derived from potential release site (PRS) 16-021(c)-99, the 260 outfall. HE was discharged in the form of HE-contaminated effluents from TA-16, and possibly other nearby sites. Secondary objectives for this investigation include (1) determining how fast the contamination, if confirmed to be present, is moving downgradient generally toward the Pajarito well field or other potential exposure points; and (2) investigating the directions of groundwater flow and the hydrologic gradients within the regional aquifer and deep perched saturated zones in and around TA-16. In addition, the design and construction standards used for CdV-R-15-3 comply with requirements for regional-aquifer characterization wells as described in the "Hydrogeologic Workplan" (LANL 1998, 59599). Thus, data collected from CdV-R 15-3 will be closely integrated with data from the regional wells drilled under that plan. The geologic, hydrologic, and geochemical data and information resulting from CdV-R-15-3 will contribute to the understanding of the vadose zone and regional aquifer in this part of the Laboratory.

CdV-R-15-3 was drilled in two phases. On January 19, 2000, a 9-in. rotary auger was used to drill to a depth of 30 ft. This hole was then reamed with a 23-in. auger to a depth of 20 ft, and an 18-in. casing was installed. On March 17, 2000, using the fluid-assisted, air-rotary, dual-wall, reverse-circulation drilling method, and a 16- in. tricone bit, drilling recommenced; the borehole was advanced to a depth of 722 ft and 13.375-in. casing was installed. Below 722 ft, using the previously described drilling method and a 12.25-in. tricone bit, the borehole was drilled to a final depth of 1722 ft. No core samples were collected during drilling.

As constructed, well CdV-R-15-3 contained six separate screened intervals (the screens are numbered in descending order from ground surface). Screens #1 through #3 were set opposite suspected zones of perched water. Screen #4 was the longest screen at 43.8 ft, spanning the surface of the regional water table. Screens #5 and #6 were set in the middle and the deep parts, respectively, of the regional aquifer in the Puye Formation.

Unanticipated stratigraphic features at CdV-R-15-3 included a thick (220 ft) Cerro Toledo interval and the absence of axial river gravels of the Puye Formation (Tpt) and Santa Fe Group sediments (Tsfuv). In addition, CdV-R-15-3 provided the westernmost known occurrence of Cerros del Rio basalts beneath the Pajarito Plateau. The unexpected occurrence of a basaltic debris flow beneath the Cerros del Rio lava suggests very active erosional processes along the western margin of the Cerros del Rio volcanic field. The Puye Formation is much thicker and more varied beneath this portion of the Pajarito Plateau than had been previously suspected.

Geochemical data for waters from CdV-R-15-3 show low total dissolved solids (TDS), and low cation and anion abundances. Analyses for HE were positive in only one of five analyzed samples, at near detection-

limit abundance (< 1 mg/L). The HE results were not repeated in a paired unfiltered sample; future monitoring will provide information about the presence or absence of HE contamination.

Possible perched saturation occurred in the upper part of the Otowi Member, Bandelier Tuff, at a depth of approximately 611 ft. Perched water, including water discharge visible on a downhole video survey, occurred within the Cerros del Rio basalts at a depth of ~980 ft. A natural gamma borehole log performed on August 11, 2000, shows that each installed well screen is open for communication with its respective targeted zone. During the first three rounds of quarterly sampling, through July 2001, water was not detected in the uppermost three screens. The top of the regional zone of saturation was found to lie at a depth of 1245 ft in the Puye Formation fanglomerate. Straddle-packer/injection tests of the Puye Formation yielded a hydraulic conductivity value of 0.25 ft/d through sediments behind screen #5, and a hydraulic conductivity value of 0.10 ft/d through sediments behind screen #6.

Extensive open-hole borehole geophysical data were obtained from well CdV-R-15-3, including borehole video, natural gamma radiation, caliper, resistivity, lithodensity, magnetic resonance, neutron porosity, spectral natural radiation, formation microimager (FMI), full bore spinner (FBS), temperature, and hole deviation.

Well CdV-R-15-3 will enable long-term monitoring of potential contaminant migration from TA-16 and, concurrently, provide the data to evaluate the effectiveness of source control cleanup actions at TA-16. Geological, geochemical, and hydrologic data from the well will provide refinement of the hydrologic conceptual model for the western half of the Laboratory. The contaminant and geohydrologic data can be used to both refine and validate numerical models of flow and transport from TA-16.

1.0 INTRODUCTION

1.1 Background

Building 16-260, an HE-machining facility established during the early 1950s, processes production quantities of HE. Machine turnings and wash water contaminated with HE and barium were discharged from this facility in volumes as large as several million gal. per year. Consequently, the outfall and the drainage channel from 16-260 are contaminated with HE and other constituents; they have been identified under the Resource Conservation and Recovery Act (RCRA) as PRS 16-021(c)-99.

Personnel within the Laboratory's Environmental Restoration (ER) Project initiated a facility investigation and developed a corrective measures study (CMS) plan for PRS 16-021(c)-99 (LANL 1998, 62413). The CMS plan, together with its addendum (LANL 1999, 64873), provided methods for (1) evaluating technologies for removal of contamination from the environment, and (2) evaluating the transport pathways, including the deep perched and regional saturated zones that potentially carry contamination from the PRS. The evaluation of these groundwater systems called for the installation of three deep boreholes. CdV-R-15-3 is the first deep borehole to be installed; CdV-R-37-2 is the second. The third deep borehole has not been identified or located at the time of this writing.

When the evaluations in the CMS plan and addendum are completed, a 260 CMS report will provide an integrated human health and ecological risk assessment using the groundwater data from these three deep boreholes as well as from other nearby ER Project wells.

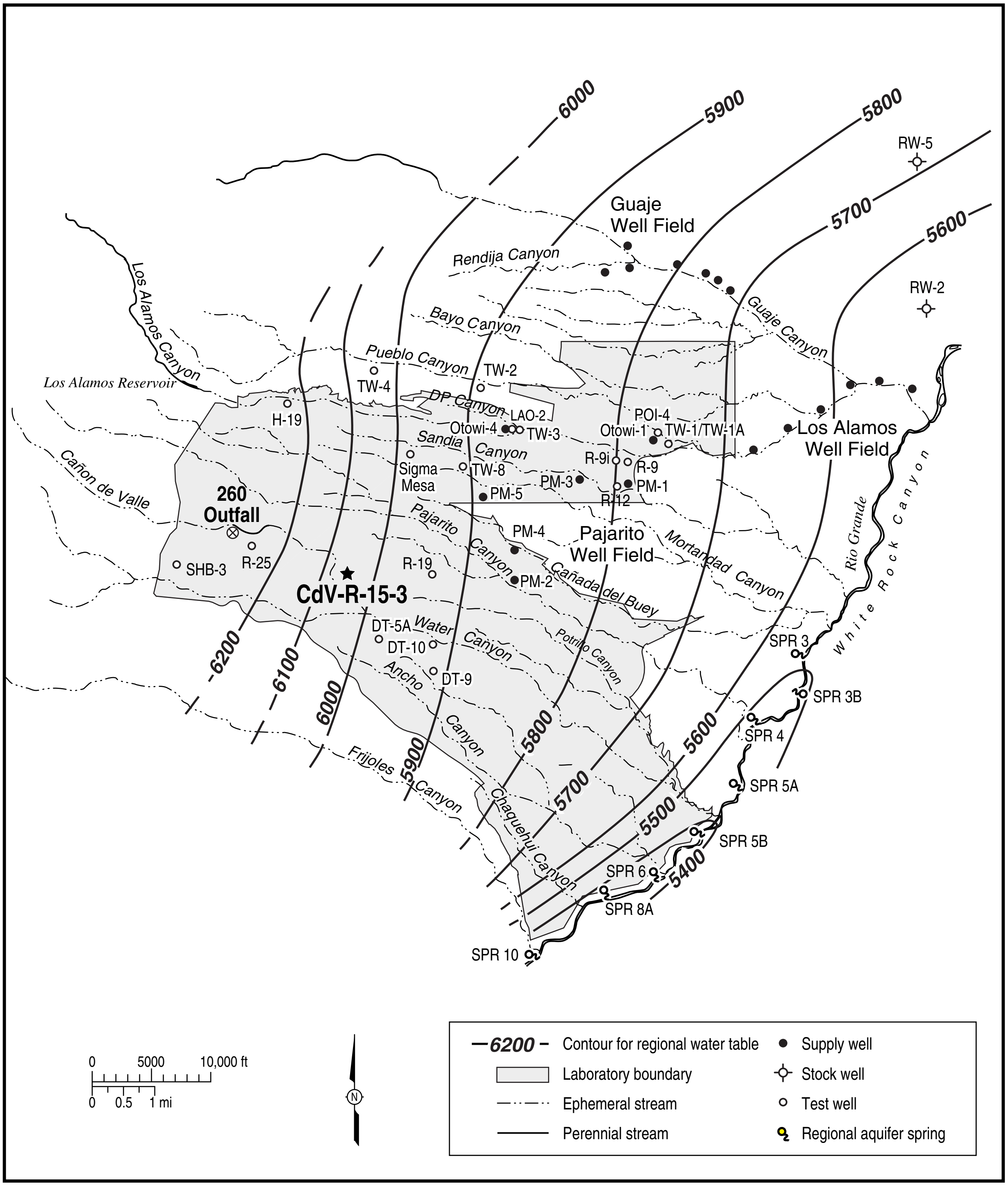
1.2 Well CdV-R-15-3

This report documents the drilling, construction, development, and hydrologic testing activities of the CdV-R-15-3 characterization well, which was installed as part of the PRS 16-021(c)-99 CMS. This well is located within TA-15 of the Laboratory. It lies approximately 800 ft east of the northeast rim of Cañon de Valle, near the head of Potrillo Canyon, on the east side of R-Site Road (see Figure 1.2-1). The well was installed by the RCRA Corrective Actions Focus Area and the Groundwater Investigations Focus Area of the Environmental Restoration (ER) Project to help determine if the HE contamination that has been detected in the perched and regional aquifers of well R-25 (located in TA-16) extends to the east.

Secondary objectives included (1) determining how fast both water and contamination, if present, have been moving downgradient generally toward the Pajarito well field or other potential exposure points, and (2) investigating the direction of groundwater flow and the hydrologic gradients within the regional and perched aquifers in the western portions of the Laboratory.

Although CdV-R-15-3 is not specifically identified in the "Hydrogeologic Workplan" (LANL 1998, 59599), the installation standards for this well comply with the requirements for characterization wells in the regional aquifer as described in that plan. Data collected from this well may be used together with data from other planned and constructed characterization wells, and from other data sources, to evaluate and update the sitewide hydrologic conceptual model. The possibility of incorporating this well into a Laboratory-wide groundwater monitoring program will be evaluated at a later date, when the results of this characterization activity are integrated with other groundwater investigations described in the hydrogeologic work plan.

Preliminary interpretations are presented here for some of the data collected, but discussion of other data is deferred until the data can be evaluated in the context of sitewide information collected from other ER Project and hydrogeologic work plan wells.



Source: Purtymun 1984, 6513.

F1.0-1 / CMS and CdV-R-15-3 COMP RPT / 052501 / LBL

Figure 1.2-1. Location of CdV-R-15-3 and other nearby deep groundwater wells

2.0 SUMMARY OF DRILLING ACTIVITIES

2.1 Equipment

CdV-R-15-3 was drilled by both Stewart Brothers Drilling Company (Stewart) and Dynatec Drilling, Inc. (Dynatec). Using a 9-in. outside diameter (OD) hollow-stem auger (HSA), Stewart augered a pilot hole to 30 ft with a CME-750 drill rig, and then overreamed with a 23-in. OD HSA to 20 ft. Dynatec drilled the remainder of the borehole with two Foremost dual-rotary 24 (DR-24) drill rigs. The second drill rig had an increased hydraulic capacity that was needed to complete the well to the targeted depth. Final well development and hydrologic testing were completed using a Universal drill rig (UDR). Dynatec provided three-man drilling crews; crew vehicles; drill hammers; dual-wall rod systems; a 1-ton flatbed truck; water trucks; and a 10-ton boom truck for handling casing, drill pipe, and heavy support apparatus such as casing jacks.

The ER Project's Field Support Facility (FSF) provided drill casings, drilling bits, a small front-end loader, the dust suppression system, field support trailers (including logging and sampling trailers), water containment tanks, drums for waste containment, a Hermit data logger and pressure transducers, a depth-to-water meter, water sampling bailers, a diesel-powered electric generator, and water sample testing and filtering apparatus. The Laboratory's geology and geochemistry group (EES-1) provided a core-logging microscope and the Water Quality and Hydrology Group (ESH-18) provided a geophysical logging trailer, a borehole video camera, and a gamma-ray logging instrument.

2.2 Schedule

On January 19, 2000, drilling was initiated with the CME-750 HSA rig. The CdV-R-15-3 borehole was augered to 30 ft with the 9-in. OD augers. The hole was then reamed with the 23-in. augers to a depth of 20 ft. A 20-ft joint of 18-in. surface casing was installed and cemented in place. After additional site preparation, including pad leveling and base-course laying, rotary drilling commenced on March 17, 2000. Fluid-assisted, air-rotary drilling was done by the dual-wall reverse-circulation method. In dual-wall reverse-circulation drilling, compressed air and drilling fluid are pumped down into the annular space located between the inner and outer drill-pipe walls, with the returns coming up the center pipe. Drilling fluid consisted of municipal water mixed with QUIK-FOAM and EZ-MUD PLUS polymers. The drilling fluid was added to the compressed-air circulating medium to help remove cuttings and stabilize the hole.

The borehole was advanced beneath the 18-in. surface casing with a 16-in. tricone bit. The 16-in. hole was drilled to 722 ft. Drilling was hindered by lost circulation and an unstable and caving borehole, which caused frequent plugging of the bit. At approximately 611 ft, the viscosity of the returned drilling fluids suggested that a perched water zone had been intersected. Field screening indicated that the returned water included products associated with HE. (Note: it was later determined that there are cross-reactivity problems with the drilling additives and the D TECH kits used for this screening, resulting in false positive HE detection.) To isolate this water zone, a string of 13.375-in. OD casing was installed to 722 ft, a cement plug was placed in the bottom of the borehole to land the casing on, and a bentonite seal was pumped into the annulus.

Below the 13.375-in. casing, the borehole was advanced using a 12.25-in. diameter tricone bit. On April 5, 2000, at a depth of 1522 ft, the drill string became stuck in the borehole. The drill string could not be rotated, raised, or lowered, and the bit was plugged. The contractor lowered a string of tubing inside the drill pipe and circulated out the accumulated drill cuttings down to the bit. The drill string and bit were freed and recovered on April 14, 2000.

After retrieving and inspecting the drill string, the 12.25-in. borehole was continued. The borehole continued to slough formation material, causing slow penetration rates, loss of returns, and problems with bit plugging. The borehole was advanced to 1722 ft, where drilling was stopped. Prior to geophysical logging, the string of 13.375-in. casing was removed. On April 27, an open borehole video and natural gamma log were made using a Laboratory-owned geophysical logging trailer. The video log revealed that the borehole had sloughed in to approximately 1680 ft. Open-hole geophysical logging by Schlumberger Geophysical Logging Services was performed on April 28 and April 29, 2000.

Well casing and screen were installed on May 2 and May 3, 2000. The total depth (TD) of the casing string was 1675 ft below ground surface (bgs). Casing centralizers were installed above and below each section of screen and approximately every 100 ft along the blank casing. The annular space was backfilled with alternating intervals of bentonite pellets and sand pack. For stability, cement seals were placed at 1490–1497 ft, 1045–1076 ft, 875–890 ft, and 0–77 ft (see Figure 7.2-1).

2.3 Production

Drilling techniques used in CdV-R-15-3 consisted of hollow-stem auger placement of a surface casing, open borehole drilling, and air-rotary underreamer placement of the 13.375-in. casing string. Production statistics are summarized in Table 2.3-1.

Table 2.3-1
Performance Statistics for CdV-R-15-3 (Air Rotary Drilling Only)

Drilling Types	16-in. Open-Hole	12.25-in. Open-Hole	13.375-in. Casing	18-in. Casing	7-in. Reverse Circulation (RC) Rods	Total (ft)[a]
Total footage drilled (ft)	700	1002	n/a[b]	n/a	1702	1702
Total footage rate (ft/hr)	12.0	8.2	n/a	n/a	9.6	9.6
Basalt footage (ft)[c,d]	n/a	49	n/a	n/a	49	49
Basalt rate (ft/hr)[d]	n/a	9.2	n/a	n/a	9.2	9.2
Puye clastics footage (ft)	n/a	821	n/a	n/a	821	821
Puye clastics rate (ft/hr)[c]	n/a	7.7	n/a	n/a	7.7	7.7
Bandelier footage (ft)[e]	700	100	n/a	n/a	800	800
Bandelier rate (ft/hr)[c,e]	12.0	11.1	n/a	n/a	11.9	11.9
Trip-in footage (ft)	n/a	n/a	722	22	5946	6690
Trip-in rate (ft/hr)[c]	n/a	n/a	54.9	34.3	241.9	174.3
Trip-out footage (ft)	n/a	n/a	722	n/a	7102	7824
Trip-out rate (ft/hr)[c]	n/a	n/a	73.6	n/a	126.7	118.8
Number of temporary seals	n/a	n/a	1	n/a	n/a	n/a

Note: Performance statistics cover entire history of drilling.

[a] TD of borehole is 1722 ft.

[b] n/a = not applicable.

[c] Rates are weighted averages over footages drilled or tripped, including breaks but excluding repairs and change-out of tools.

[d] Basalt footage and rates are for Cerros del Rio basalt.

[e] Bandelier footage and rates include Tshirege Member, Otowi Member, and the Cerro Toledo interval.

The total footage drilled by the different drilling techniques was 1722 ft. The total footage drilled does not include the footage of one drill system or casing size as they tripped in or out of another drill system or casing size. The total trip-in footage was 6690 ft, and the total trip-out footage was 7824 ft. Trip-in footage includes footage of drill casing and pipe lowered into the hole without drilling. Trip-out footage includes footage of drill casing and pipe removed from the borehole either upon completion or for drill-tool inspection. (The trip-in footage can differ from trip-out footage due to the amount drilled between events.)

2.3.1 Open Borehole Drilling

The entire borehole was drilled open-hole. The pilot hole was augered to 30 ft with a 9-in. OD HSA and then to 20 ft with a 23-in. OD HSA auger to set surface casing. A 16-in. tricone bit on 7-in. dual wall RC rods was advanced to 722 ft, at an average rate of 12.0 ft/hr. Casing (13.375 in.) was landed at 722 ft to isolate potential perched water which field-screening data suggested might contain products associated with HE. A 12.25-in. tricone bit on 7-in. RC rods was then advanced to a TD of 1722 ft, at an average rate of 8.2 ft/hr.

2.3.2 Core Drilling

Although coring was originally planned, it was not attempted at CdV-R-15-3 because ER Project personnel decided that the geophysics performed on an open borehole would provide the desired characterization data, and that hydraulic tests in the well could take the place of laboratory tests on core. These changes to the plan were discussed with NMED personnel at the well site.

2.3.3 Casing Advancement

Casing advancement was not necessary and therefore not attempted at CdV-R-15-3. Casing (13.375 in.) was placed in the previously drilled open borehole to a depth of 722 ft; however, the drilling technique of casing advancement while using an underreamer bit was not necessary.

3.0 GEOLOGY

The following geologic units were encountered in CdV-R-15-3 (in descending order):

1. alluvium and soil,
2. the Tshirege Member of the Bandelier Tuff, including the basal Tsankawi Pumice Bed,
3. tephras and volcaniclastic sediments of the Cerro Toledo interval,
4. the Otowi Member of the Bandelier Tuff, including the basal Guaje Pumice Bed,
5. an upper subunit of the Puye Formation fanglomerate facies,
6. basaltic rocks of the Cerros del Rio volcanic field, and
7. a lower subunit of Puye Formation fanglomerates.

Depths and elevations of the contacts between these units are shown in Figure 3.0-1, with a comparison to the predicted stratigraphy based on the 3-D geologic model available at the time drilling began. Notable differences between the predicted and as-drilled stratigraphy are the greater thickness of the Cerro Toledo interval (Qct), the lesser thickness of the Otowi Member of the Bandelier Tuff (Qbof), the thinner sequence of Cerros del Rio lavas (Tb4), the absence of axial facies river gravels (Tpt; Totavi), and the absence of Santa Fe Group sediments (Tsfuv).

Figure 3.0-2 shows the location of CdV-R-15-3 and the line of cross-section for Figure 3.0-3. An interpretive east-west cross-section, incorporating results from recent drilling at R-19, is shown in Figure 3.0-3. Descriptions of geologic units are based on examination of cuttings and thin sections (a petrographic description of thin sections is provided in Appendix C), on geochemical data acquired by X-ray fluorescence (XRF), on mineralogic data acquired by X-ray diffraction (XRD), on geophysical logs, and on drilling information.

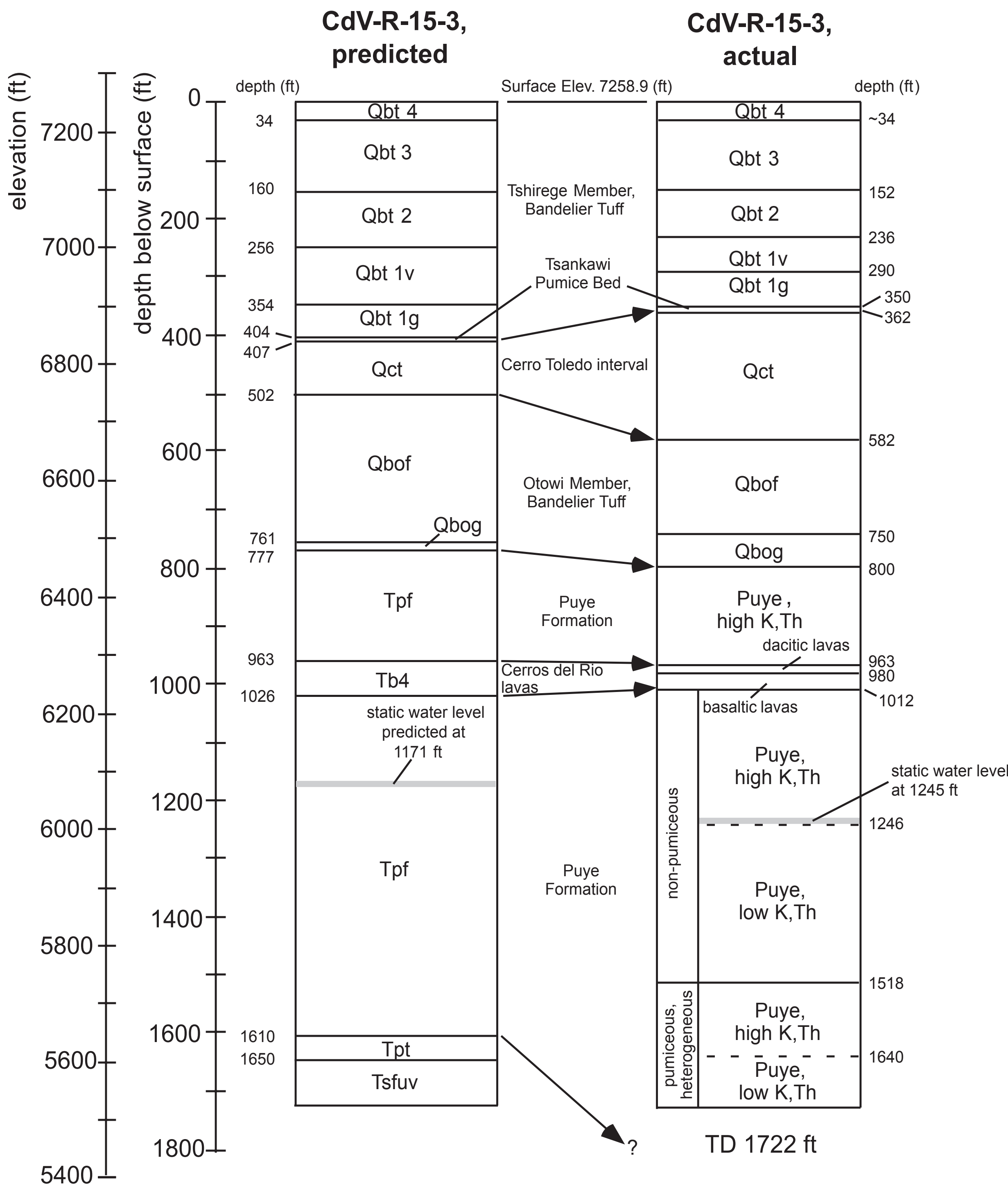
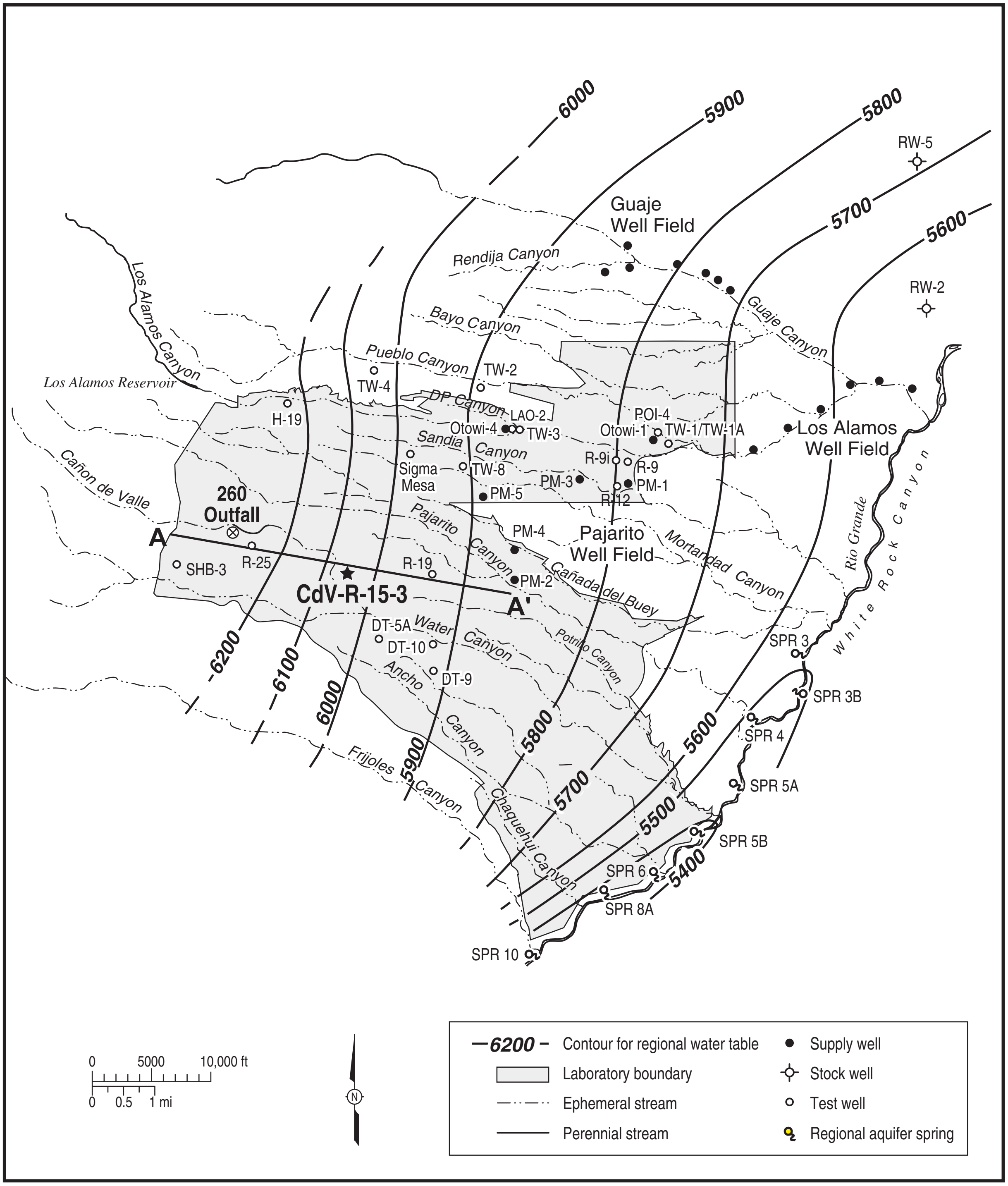


Figure 3.0-1. Stratigraphy predicted at CdV-R-15-3 from the 1999 3-D geologic model, compared with the stratigraphy interpreted from cuttings, geophysical logs, and video logs



Source: Purtymun 1984, 6513.

F3.0-2 / WELL CdV-R-15-3 COMP RPT / 041102 / LBL

Figure 3.0-2. Location of well CdV-R-15-3 and the line of cross-section for Figure 3.0-3

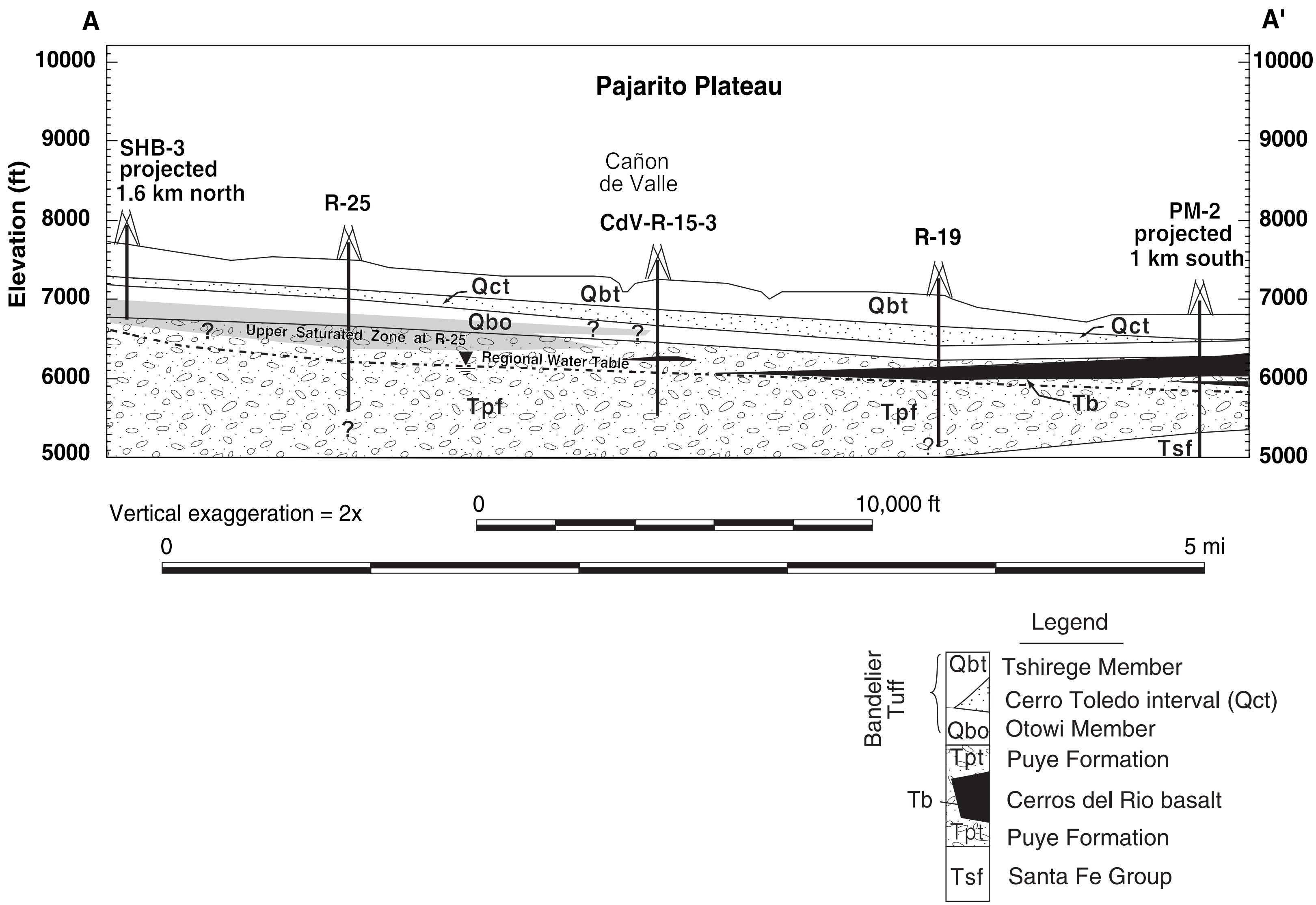


Figure 3.0-3. WNW-ESE cross-section through the southern part of the Laboratory, showing geology in the vicinity of CdV-R-15-3 (see Figure 3.0-2 for location of cross-section)

A summary of unit characteristics is given in the following sections, and a detailed lithologic log is provided in Appendix B. Composite borehole geophysics logs from Schlumberger were used, along with analysis of cuttings, to define the in situ lithology at CdV-R-15-3, supplemented by video logs and a natural-gamma log collected using the Laboratory gamma tool (Figure 3.0-4). No core was collected during the drilling of CdV-R-15-3, so all studies of borehole materials were based on cuttings. Cuttings were collected by reverse circulation, thereby minimizing the admixture of materials from upper portions of the borehole (see section 2.2).

Samples that were representative of the Otowi Member, Cerros del Rio lavas, and Puye Formations were selected for chemical (XRF) and mineralogic (XRD) analysis. Table 3.0-1 lists these samples and the reasons for their selection. Samples were selected to represent most of the horizons at which well screens and Westbay sampling ports were installed; in addition, samples were selected for chemical or mineralogic analysis where unusual volcanic or sedimentary compositions were suspected. Splits of all of the samples listed in Table 3.0-1 and six additional samples were thin-sectioned for petrographic analysis. Results of XRF analyses are listed in Table 3.1-1, and results of XRD analyses are listed in Tables 3.1-2 and 3.1-3. These results, and the results of petrographic analyses, are cited throughout the following descriptions of geologic units at CdV-R-15-3.

Table 3.0-1
Samples Selected for Chemical (XRF) and Mineralogic (XRD) Analyses

Depth (ft)	Stratigraphic Relations	Nature of Sample	XRF	XRD	Rationale for Selection
617–622	Otowi Member	< 1-mm size fraction	X	X	Characterization of the ash flow at screen #1
967–972	Cerros del Rio flow top	1- to 2-mm size fraction	X	X	Characterization of the fragmented basalt at screen #3
972–977	Cerros del Rio lava	Hand-picked	X	X	Characterization of the lava flow at screen #3
982–987	Cerros del Rio lava	Hand-picked	X	—	Characterization of the lower lava composition
1002–1007	Cerros del Rio lava	Hand-picked	X	—	Characterization of basaltic rubble unit
1272–1277	Puye (low potassium, thorium)	2- to 4-mm size fraction	X	X	Characterization of the sediments at screen #4
1347–1352	Puye (low potassium, thorium)	2- to 4-mm size fraction	X	X	Characterization of the sediments at screen #5
1447–1452	Puye sand (low potassium, thorium)	0.25- to 1-mm size fraction	X	X	Characterization of a distinctively sandy Puye unit
1642–1647	Puye (pumiceous)	2- to 4-mm size fraction	X	X	Characterization of the sediments at screen #6
1717–1722	Puye (pumiceous; relatively pumice-poor)	2- to 4-mm size fraction	X	X	Characterization of one of the deepest sampled Puye horizons

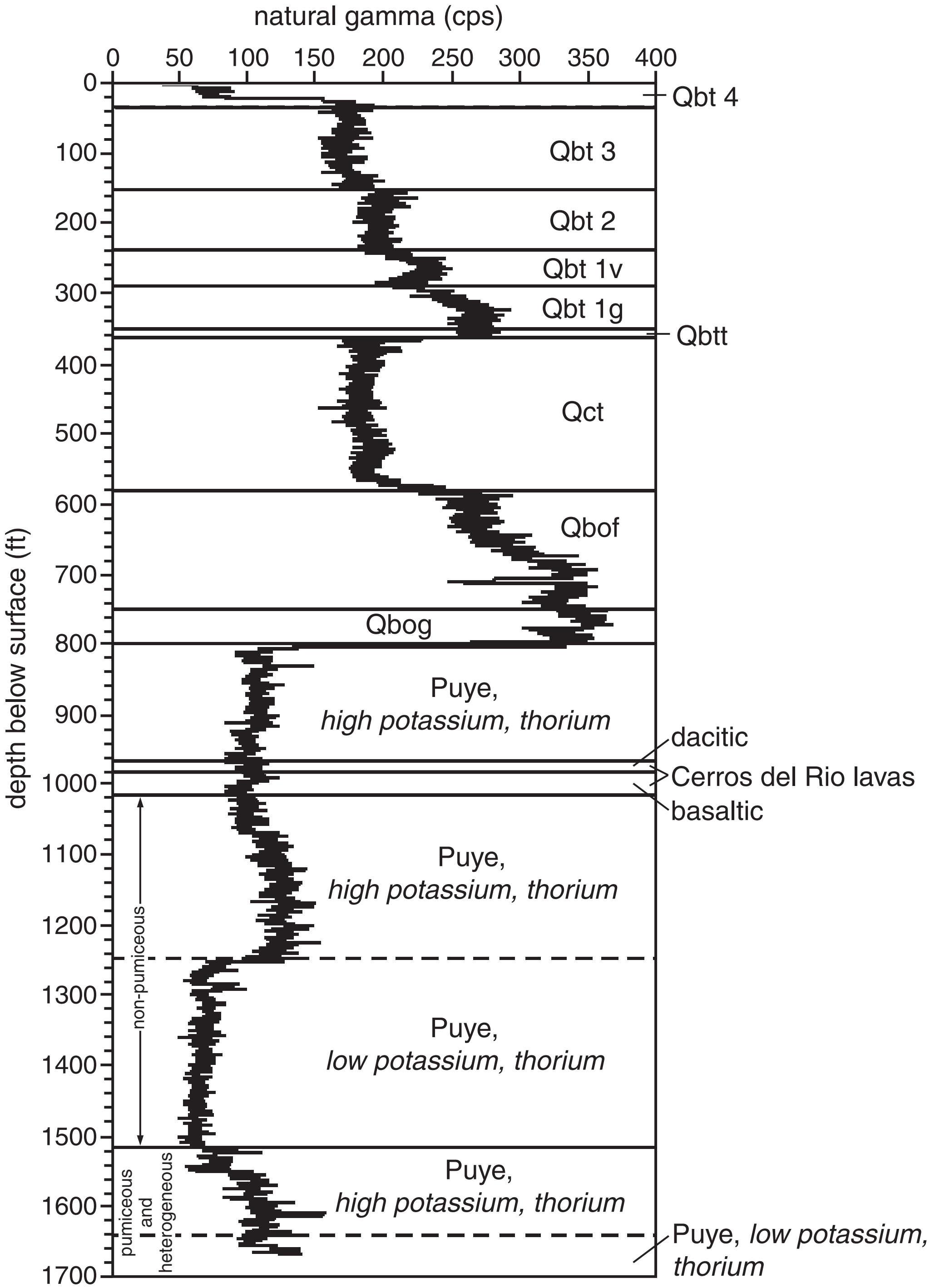


Figure 3.0-4. Natural gamma signal from CdV-R-15-3 (data from 0 to 575.75 ft collected 3/25/00; data from 575.75 to 1680 ft collected 4/27/00; an 18-in. steel surface casing extends to a depth of 20 ft)

3.1 Stratigraphy at CdV-R-15-3

The stratigraphy encountered in CdV-R-15-3 is graphically presented in the lithologic log (Appendix B).

3.1.1 Disturbed Alluvium and Mesa-Top Soil (0 to 5 ft)

Soil was penetrated from the surface to a depth of approximately 5 ft (Appendix B). This material had been disturbed; abandoned building debris mixed with alluvium and soil provide evidence of demolition and backfilling. The thickness of the soil cover, with alluvial clasts, was estimated from the first encounter of tuff with the 9- in. OD auger. The soil is sandy, dry, and contains abundant 1- to 2-mm crystals of quartz and chatoyant sanidine derived principally from Unit 4 of the Tshirege Member of the Bandelier Tuff.

3.1.2 Tshirege Member of the Bandelier Tuff

The Pleistocene Tshirege Member of the Bandelier Tuff consists of multiple cooling units, designated downsection as units Qbt 4, 3, 2, 1v, and 1g. Nomenclature and definition of these units follows the usage of Broxton and Reneau (1995, 49726).

3.1.2.1 Qbt 4 (5 to ~34 ft)

A thin sequence of unit Qbt 4 of the Tshirege Member was encountered below the alluvium and soil. Qbt 4 consists of massive, moderately welded, devitrified, ash-flow tuff. A single initial collection of cuttings from 20 to 42 ft at CdV-R-15-3 obscures the location of the Qbt 4/Qbt 3 contact, and borehole logs do not adequately cover this contact. Therefore, the approximate location of the contact is derived from local outcrop control incorporated in the 3-D geologic model. The ash flows of Qbt 4 typically include a basal interval of a few feet comprised of crystal-rich surge deposits. Compared to the underlying units of the Tshirege Member, Qbt 4 is poorer in silica and richer in titanium, iron, and barium (Broxton et al. 1995, 54709).

3.1.2.2 Qbt 3 (~34 to 152 ft)

Unit Qbt 3 of the Tshirege Member was encountered between the depths of 34 ft (estimated) and 152 ft (observed). Qbt 3 consists of massive, moderately welded to nonwelded, devitrified, ash-flow tuff. Compositionally, this unit is more typical of the lower Tshirege ash flows, which are distinctly less mafic than Qbt 4. Borehole caliper logging indicates significant washout from ~120 to 154 ft, at a thickness and position expected for the nonwelded base of Qbt 3 (compare the stratigraphy mapped just to the north at Pajarito Mesa; Broxton et al. 1995, 54709). The contact between Qbt 3 and Qbt 2 corresponds with a rise in the natural gamma signal in data collected with the Laboratory’s gamma tool (Figure 3.0-4).

3.1.2.3 Qbt 2 (152 to 236 ft)

Unit Qbt 2 of the Tshirege Member was encountered between depths of 152 ft and 236 ft. This unit consists of massive, slightly to moderately welded, devitrified, ash-flow tuff. Even though completely vapor-phase altered, in most locales unit Qbt 2 differs from the upper parts of the Tshirege by its silica-phase assemblage of only tridymite and quartz, lacking the cristobalite which is common in the overlying zones of vapor-phase alteration (Broxton et al. 1995, 54709).

The contact between unit Qbt 2 and Qbt 1v is difficult to distinguish based on the analysis of cuttings. However, the two units have subtly different physical properties, and a drop in formation density beginning at the 236-ft depth is accompanied by a rise in the natural gamma signal (Figure 3.0-4). These transitions at the 236-ft depth are interpreted to coincide with the Qbt 2/Qbt 1v contact.

3.1.2.4 Qbt 1v (236 to 290 ft)

Unit Qbt 1v of the Tshirege Member was encountered between depths of 236 ft and 290 ft. The lower contact of Qbt 1v is marked by the first appearance of glass, indicating the transition into unit Qbt 1g. Unit Qbt 1v consists of massive, poorly consolidated, devitrified, nonwelded, ash-flow tuff. The use of *v* in the unit symbol refers to the extensive vapor-phase alteration in this upper part of Qbt 1. This contrasts with the lower part, Qbt 1g, in which primary glass is largely preserved, with little vapor-phase alteration. The borehole logs indicate that the abundances of both clay and capillary-bound water are elevated in the 280- to 300-ft depth interval. The transitional boundary from vapor-phase alteration to vitric tuff is apparently a zone of local moisture accumulation. The natural gamma log also indicates a distinct minimum in this transition zone (Figure 3.0-4).

3.1.2.5 Qbt 1g (290 to 350 ft) and Tsankawi Pumice Bed (350 to 362 ft)

Unit Qbt 1g of the Pleistocene Tshirege Member and the basal Tsankawi Pumice Bed (unit Qbtt) were encountered between depths of 290 and 362 ft. This unit consists of massive, poorly consolidated, vitric, nonwelded, ash-flow tuff. A deposit of the Tsankawi Pumice Bed occurs from 350 ft to 362 ft.

At ~290 ft, the gamma signal attributable to thorium in the borehole log rises relative to the upper Tshirege units [based on Schlumberger's hostile environment gamma-ray sonde (HNGS); see section 3.2]. The thorium gamma signal remains elevated to a depth of ~354 ft, where it drops across the Tsankawi Pumice Bed. Within Qbt 1g, from ~310 to 335 ft, clay and capillary-bound water are elevated to the extent also seen at the Qbt 1v/Qbt 1g contact. The Tsankawi Pumice Bed is marked by exceptionally high capillary-bound water. The highest readings of pore saturation observed between the surface and ~750 ft occur within the Guaje Pumice Bed.

3.1.3 Tephras and Volcaniclastic Sediments of the Cerro Toledo Interval (362 to 582 ft)

The Pleistocene Cerro Toledo interval (Qct) is thick at CdV-R-15-3, extending from 362 to 582 ft in the drill hole (Appendix B). The thickness of this unit, 220 ft, is much greater than the thickness predicted by the 3-D geologic model at the time of drilling (95 ft; Figure 3.0-1) but is comparable to the unexpected thickness of Cerro Toledo sediments logged at drill hole R-19, just to the east (266 ft).

In view of the unexpected thickness of Cerro Toledo deposition in this part of the Laboratory site, revisions to the 3-D geologic model are needed. The correspondingly less-than-expected thickness of the Otowi Member indicates an erosional low, developed on the Otowi Member, in which Cerro Toledo sediments accumulated. Further drilling, as called for in the addendum to the CMS plan (LANL 1999, 64873), will provide the information necessary to revise the geometry of the erosional and depositional relations between the Cerro Toledo and the underlying Otowi Member.

The Cerro Toledo deposits are comprised of a mixture of Tschicoma Formation intermediate-composition volcanic detritus and altered volcanic clasts with pumice and ash from volcanic centers of Cerro Toledo age. The Cerro Toledo deposits are generally more fine-grained than the Puye Formation fanglomerates which predate the Bandelier Tuff eruptions. A video log of the open borehole indicates that clast sizes in the Cerro Toledo interval at CdV-R-15-3 are generally ~5 cm and are seldom as large as 8 cm; many intervals of up to 10- to 20-ft thickness are essentially composed of fine detritus with few visible clasts. (The video log is available from the ER Project's Records Processing Facility; LANL 2000, 70123.) The ~8-cm limit on upper clast size in the Cerro Toledo interval contrasts with the sediments of the Puye Formation, where clasts up to and exceeding the borehole diameter (~30 cm) are common. Unlike the Puye Formation, the Cerro Toledo produces few cuttings of > 4 mm. Geochemical analysis of cutting-size fractions from drill hole R-19, ~1.3 mi to the east (see Figure 3.0-2 and Figure 3.0-3), shows that the intermixture of local and distal sources for the Cerro Toledo deposits results in notable compositional differences between the > 2-mm and < 1-mm size fractions, unlike the geochemical homogeneity in size fractions of the Puye Formation (Broxton et al. 2001, 71253).

Three thin sections were prepared from the 2–4 mm Cerro Toledo cuttings from near the top (372- to 377-ft depth), in the middle (467- to 472-ft depth), and near the bottom (572- to 577-ft depth) of the Cerro Toledo sequence at CdV-R-15-3. The uppermost sample contains ~30% aphyric to sparsely quartz-albite-sanidine porphyritic vitric pumice; the remainder of this sample consists of ~30% intermediate-composition plagioclase + pyroxene ± amphibole ± biotite lavas of the Tschicoma Formation and ~40% highly altered silicic to intermediate-composition lavas of uncertain origin. The middle sample contains ~35% aphyric to sparsely quartz-sanidine porphyritic pumice, of which ~75% are vitric and ~25% are extensively clay-altered. Intermediate-composition lavas of the Tschicoma Formation in this sample contain plagioclase + pyroxene ± amphibole ± biotite ± quartz (~30% of the sample) and altered silicic to intermediate-composition lavas with opal-lined voids forming the remaining ~35%. The lowest sample contains ~10% aphyric to sparsely quartz + albite + sanidine porphyritic vitric pumice along with plagioclase + clinopyroxene Tschicoma lavas with a fine-grained to glassy matrix (~30%), fine-grained felsic lavas (~25%), heavily oxidized porphyritic intermediate-composition lavas with clay-altered feldspar phenocrysts (~35%), and one fragment of strained-quartz sandstone with micaceous matrix. Within the Cerro Toledo, the lowermost sample is most distinctive in that it contains much less pumice within a suite of heavily altered volcanic lavas. The sandstone fragment in the lowest sample is of uncertain origin; the sandstone as well as the highly oxidized altered lavas may represent wall-rock lithologies entrained as accidental fragments in early Cerro Toledo explosive eruptions.

The relative homogeneity of clast lithologies within the upper Cerro Toledo interval at CdV-R-15-3 corresponds to the little variability in the properties measured by borehole logging through this zone. Caliper-measured borehole dimensions, gamma signals, capillary and bound water, and neutron measures of water residence environment are all strikingly homogeneous. This homogeneity contrasts with the highly heterogeneous nature of all of these properties over comparable section thicknesses within the deeper Puye sediments. There is a modest but measurable rise in gamma-determined thorium content in the lower 22 ft of the Cerro Toledo deposits (the 560- to 582-ft depth), represented by the sample at 572- to 577-ft depth. The rise in thorium content may be associated with the abundance of heavily oxidized and clay-altered volcanic lavas in this sample. Incorporation of more porphyritic pumice in the lowest 10 ft (572–582 ft), which coincides with the steepest rise in the natural gamma log, appears to be associated with incorporation of Otowi ash and pumice.

3.1.4 Otowi Member of the Bandelier Tuff; Ash Flows (Qbof; 582 to 750 ft) and Guaje Pumice Bed (Qbog; 750 to 800 ft)

Tuffs of the Pleistocene Otowi Member, including ash flows (Qbof) and the basal Guaje Pumice Bed (Qbog), were encountered between depths of 582 and 800 ft. At CdV-R-15-3, the ash flows of the Otowi Member consist of massive, poorly consolidated, vitric, nonwelded tuff. The Guaje Pumice Bed occurs beneath the ash flows from a depth of 750 ft to 800 ft.

Borehole logs for the Otowi Member indicate properties comparable to unit Qbt 1g of the Tshirege Member, which is also a vitric nonwelded tuff. An interval of increased large-pore saturation was logged at ~612–615 ft, corresponding to the location of screen #1 (617.7- to 624.5-ft depth). A thin section of 2–4 mm fragments from the 617- to 622-ft depth consists of ~85% vitric nonwelded Otowi pumice with quartz-sanidine-albite phenocrysts and ~10% dacitic Tschicoma lava fragments, plus one fragment of silicified lava of uncertain origin and one fragment of immature arkosic sandstone. The non-Otowi constituents represent accidental wall-rock materials incorporated into the ash flow. Chemical analyses of a split of this Otowi sample are shown in column 1 of Table 3.1-1. The mineralogic analysis by XRD (row 1, Table 3.1-2) shows the very high quartz content, with a lack of, or low abundance of, tridymite and cristobalite, typical of vitric Otowi ash flows. Clay (smectite) was not detected in this sample by XRD analysis and was not observed in thin section, indicating that the possible water occurrence at screen #1 was not associated with alteration of glass to clay.

The Guaje Pumice Bed, beginning at ~750 ft, is an interval with considerably larger pore structure and greater neutron-logged water content than the overlying ash flows. Within the Guaje Pumice Bed, bound water and coarser pore sizes occur in two intervals: at ~768–775 ft and at ~792–798 ft. The lower of these intervals is just above screen #2 (800.8–807.8 ft), where any water from the Guaje can be transmitted through the annular fill of 20/40 sand that extends down to the screened interval.

3.1.5 Puye Formation (Upper Fanglomerate Sequence; 800 to 963 ft)

An upper fanglomerate sequence of the Puye Formation extends from depths of 800 to 963 ft (Appendix B). Both the upper and lower Puye fanglomerate sequences at CdV-R-15-3 consist of coarse volcaniclastic sediments as described by Griggs (1964, 8795) and by Waresback (1986, 58715). The volcaniclastic sediments are dominated by rounded clasts of various lavas. A thin section of 2–4 mm clasts from the 617- to 622-ft depth consists almost entirely of Tschicoma Formation dacites with anhydrous mafic phenocrysts (clinopyroxene and orthopyroxene); most of the fragments observed contain rounded quartz phenocrysts along with the ubiquitous plagioclase phenocrysts. Altered hornblende is rare. The thin section also contained one fragment of a metamorphic rock containing quartz, sieved plagioclase, epidote, and chlorite. The video log (LANL 2000, 70128) collected from the open borehole indicates that clast sizes in this section of the Puye commonly exceed 15 cm, with abundant clasts exceeding the borehole diameter (~30 cm) in the interval from the 882- to 928-ft depth.

Borehole logs show a large drop in the thorium and uranium gamma signals, but not the potassium signal, at the transition from the Guaje Pumice Bed into the dacite detritus of the Puye Formation. Clay and capillary-bound water remain low throughout the upper sequence of the Puye Formation, with the exception of an interval of possible clay alteration at the ~918- to 925-ft depth.

3.1.6 Cerros del Rio Dacitic to Basaltic Lavas (963 to 1012 ft)

Lava flows of the Cerros del Rio volcanic field occur from depths of 963 to 1012 ft. These flows consist of dacitic flow-top rubble from 963 to 970 ft, a massive dacitic flow from 970 to 980 ft, a massive alkalic basalt flow from 980 to 988 ft, a rubbly alkalic-basalt flow base from 988 to 990 ft, and an alkalic-basalt lava boulder bed from 990 to 1012 ft (Appendix B). From 965 to 997 ft, the gamma log is essentially flat, although this 32-ft-thick sequence includes both dacitic and alkali-basalt compositions. The absence of a significant deviation in gamma signal between these two compositions indicates little difference in potassium, uranium, and thorium content, unlike other dacite-to-basalt transitions in the Cerros del Rio lavas (e.g., at R-22; Ball et al. in preparation) where the dacitic lavas have significantly higher natural gamma signals than the basalts. At CdV-R-15-3, the gamma signal is diminished only within the lower part of the basaltic rubble, below the base of the massive flows at 988 ft. Water within connected pores is suggested by neutron logging of the interval from ~966 to 970 ft, which corresponds with the zone of flow-top rubble observed in the borehole video (LANL 2000, 70128). Screen #3 (964.8–980.9 ft) spans this interval.

3.1.6.1 Dacitic Upper Cerros del Rio Lavas (963 to 980 ft)

The upper Cerros del Rio lavas at CdV-R-15-3 are dacitic, with a silica composition of ~67% (columns 2 and 3, Table 3.1-1; column 2 represents bulk cuttings and column 3, a hand-picked separate of the dacite lava). These two samples of the dacitic lava were analyzed for chemical composition (XRF) and mineralogy (XRD), as well as in thin section.

One thin section was made from the 1–2 mm cuttings at the 967- to 972-ft depth, corresponding to the material used for XRD and XRF, in order to examine the bulk material at Westbay screen #3. The thin section shows that the bulk cuttings are dominated by a single lithology representing the dacitic lava of the upper Cerros del Rio flow (> 90%); the other fragments are of oxidized red dacitic scoria and yellow-glass dacitic scoria which are probably related to the lava flow top. The dacitic lava contains phenocrysts of euhedral plagioclase (~0.6 mm) with oscillatory zoning, euhedral clinopyroxene (~0.3 mm) with slight yellow-to-clear pleochroism, subhedral and slightly altered orthopyroxene (~0.1 mm), and amphibole. The rare amphibole phenocrysts are highly oxidized and red.

A second thin section was made of hand-picked dacite lava fragments from the 972- to 977-ft depth, near the top of the massive flow unit. This sample is almost identical to the cuttings at 967-972 ft depth, except that the phenocrysts are larger (~1 mm plagioclase, ~0.5 mm clinopyroxene, and ~0.2 mm orthopyroxene). Amphibole phenocrysts in the deeper sample are rarer and altered to black oxide-rich masses. In both samples the plagioclase phenocrysts have strong oscillatory zoning with little corrosion or sieving. Slight difference is seen in the XRD data (Table 3.1-2, rows 2 and 3), where the upper sample has more quartz, less tridymite, and more glass. Quartz, tridymite, and cristobalite occur not as phenocrysts but within the fine-grained matrix of these dacitic lavas.

3.1.6.2 Basaltic Lower Cerros del Rio Lavas (980 to 1012 ft)

The lower Cerros del Rio lavas at CdV-R-15-3 are basaltic, with silica compositions of ~53%; high strontium contents of ~860–870 ppm, along with high K_2O+Na_2O contents, indicate alkali basalt (columns 4 and 5, Table 3.1-1). Two thin sections of hand-picked fragments from this lithology were examined: one from 982–987 ft within the massive lava, and one from 1002–1007 ft within the basaltic boulder bed. In thin section, both samples are of olivine basalt with abundant iddingsite-rimmed olivine phenocrysts in a fine-grained matrix. The sample from 982-987 ft has ~10% subhedral olivine phenocrysts of ~0.3 mm and quartz xenocrysts of ~0.2 mm. This sample also has ~5% of strongly sieved and anhedral plagioclase phenocrysts of up to 0.4 mm, with oscillatory zoning. The lower sample at 1002-1007 ft has larger and more euhedral olivine phenocrysts, to 0.5 mm, but these are less abundant (~7%). Groundmass clinopyroxene in this sample is more prominent than in the upper sample, principally because the matrix is more coarse-grained. The lower sample of the alkalic basalt lacks quartz xenocrysts.

The interval from 990 to 1012 ft produced cuttings composed almost entirely of basalt, although analysis of the borehole video indicates that the section sampled is made up of boulders up to ~30 cm. Compared to the overlying lava flows, the basaltic boulders at the 990- to 1012-ft depth have diminished formation density and higher clay-bound water content, suggesting extensive alteration within the blocky material. Emplacement of this unit immediately before Cerros del Rio deposition of a compositionally similar flow at CdV-R-15-3 suggests a related origin, perhaps as a debris flow shed from a nearby Cerros del Rio highland. A general absence of scoria, except in the lowermost cuttings from this interval, indicates that the source area for the debris is unlikely to be a cinder cone.

3.1.7 Puye Formation (Lower Fanglomerate Sequence; 1012 ft to TD at 1722 ft)

Beneath the Cerros del Rio basaltic boulder bed, a thick lower sequence of the Puye Formation extends from 1012 ft to TD at 1722 ft (Appendix B). These Puye deposits consist of coarse to moderately fine volcaniclastic sediments with abundant 2- to 4-mm clasts to a depth of ~1518 ft, where the abundance of 2- to 4-mm clasts diminishes and the > 4-mm fragments predominate in the cuttings. Relying principally on the Schlumberger potassium, thorium, and uranium spectral gamma logs, it is possible to delineate four subdivisions of the Puye Formation fanglomerates beneath the Cerros del Rio lavas. These subdivisions are a thorium- and potassium-rich interval from 1012 to 1246 ft, a thorium- and potassium-poor interval from 1246 to 1518 ft, another thorium- and potassium-rich interval from 1518 to ~1640 ft, and a zone of gradually diminishing thorium and potassium content that begins at ~1640 ft and probably extends to TD at 1722 ft (the Schlumberger gamma log ends at 1669 ft). These subdivisions can also be seen as overall gamma signal variations on the total natural gamma log of Figure 3.0-4. A major stratigraphic distinction occurs below 1518 ft, where pumice-bearing zones begin to appear intercalated between intervals of pumice-poor fanglomerate. This distinction is used to divide the fanglomerate sequence below 1012 ft into two major subunits: non-pumiceous and pumiceous (as described below).

3.1.7.1 Non-pumiceous Puye Fanglomerates (1012 to 1518 ft)

The upper thorium- and potassium-rich interval (1012–1246 ft) can be further subdivided into a low natural-gamma section above 1060 ft and a higher natural-gamma section below this depth (Figure 3.0-4). The full interval has a relatively uniform and low content of clay and capillary-bound water. The borehole video log (LANL 2000, 70128) indicates common occurrences of clasts 15–30 cm in size at 1012–1086 ft, a deposit of finer detritus (≤ 8 cm) at 1086–1106 ft, another sequence with 15–30 cm clasts common at 1106–1185 ft, and a lower sequence at 1185–1246 ft with few clasts coarser than 15 cm. The FMI tool (see section 3.2.2.9) provides little information for this interval because the highest FMI record is at ~1245 ft. Both the caliper log and the borehole video show the borehole wall to be relatively smooth throughout the interval of 1012–1246 ft.

The thorium- and potassium-poor interval of 1246–1518 ft includes zones of notably high pore saturation at 1250–1254 ft, 1336–1342 ft, 1354–1360 ft, and 1494–1500 ft. As in the thorium- and potassium-rich interval above, both the caliper log and the borehole video show the borehole wall to be relatively smooth in this interval. The natural gamma log shows this interval to have a distinctly low signal (Figure 3.0-4). Thin sections of 2–4 mm cuttings from the 1272- to 1277-ft depth and from the 1347- to 1352-ft depth consist predominantly of two-pyroxene dacites; amphibole is rare and generally altered. The bulk chemical compositions of these two samples are very similar (columns 6 and 7, Table 3.1-1). The sample from the 1347- to 1352-ft depth consists predominantly of dacitic lava fragments that strongly resemble the two-pyroxene dacite lava at the 972- to 977-ft depth (see section 3.1.6.1), which is assigned to the Cerros del Rio lavas because of its continuity with the underlying alkali-basalt lava that is typical of the Cerros del Rio. The resemblance between the dacites extends to their chemical compositions (compare columns 3 and 7, Table 3.1-1). The similarity between Puye and Cerros del Rio samples suggests that the distinctions between volcanic sources for these units, which overlap in age, may be difficult to draw if a sample is analyzed out of context. This similarity also introduces the possibility that there may be a region beneath the LANL site where Tschicoma and Cerros del Rio lavas overlap. Only further data on distributions and sources of the lavas can resolve this question.

Clast sizes in situ are difficult to estimate in the 1246- to 1518-ft Puye interval because of the poor quality of the borehole video. Cuttings collected from 1407 to 1522 ft are principally made up of sand < 2 mm in size, with few coarser clasts. A thin section made from 0.25–1 mm particles at the 1447- to 1452-ft depth within this sandy unit consists almost entirely of dacitic lava matrix fragments. Less than 1% of the sandy fragments are pumiceous glass, and a few percent are detrital dacitic phenocrysts (plagioclase, clinopyroxene, and altered amphibole). In chemical composition, this sand is more siliceous than the overlying coarser Puye sediments (column 8, Table 3.1-1). Mineralogically, it is similar to the coarser sediments, with no detectable clay alteration in XRD analysis (rows 4, 5, and 6, Table 3.1-2).

The FMI tool shows that the 1246- to 1518-ft Puye interval is quite varied in texture, including sequences up to 12 ft thick that contain cobbles > 25–30 cm, gravel sequences up to 20 ft thick, and sand sequences like the sample at the 1447- to 1452-ft depth that are typically 1 to 4 ft thick. The FMI results also indicate dips generally less than 10° in the sedimentary layers, with a distribution of dips that suggests no consistent structural tilting. The screen at the water table, screen #4 (1235.1–1278.9 ft), includes the uppermost zone of high pore saturation (1250–1254 ft), as interpreted from the geophysical logs. Screen #5 (1348.4–1355.3 ft) is situated across the transition into the zone of high pore saturation at 1354–1360 ft.

3.1.7.2 Heterogeneous Pumiceous Puye Fanglomerates (1518 ft to TD at 1722 ft)

The Puye sequence from 1518 ft to TD at 1722 ft is distinguished from the overlying Puye fanglomerates by the occurrence of multiple horizons with a significant component of pumice. However, pumice is not found throughout this sequence.

A thin section of 2–4 mm cuttings from the 1592- to 1597-ft depth contains no pumice but differs, nevertheless, from the fanglomerates above 1518 ft by its great variety of intermixed volcanic lithologies. Whereas the samples of fanglomerate above 1518 ft rarely have more than four to five different intermediate-composition lavas and may be virtually monolithologic (e.g., the sample at the 1347- to 1352-ft depth), samples below 1518 ft typically represent ten different volcanic sources or more in a standard thin section of 20–30 fragments. Two-pyroxene dacites, and other dacites with dominantly anhydrous mafic phenocrysts, are still present but they occur along with more common amphibole-bearing dacites and with the additional occurrence of quartz- and biotite-porphyritic dacites.

Thin sections from the 1642- to 1647-ft depth and the 1717- to 1722-ft depth represent pumice-bearing horizons and contain 23% and 10% pumice, respectively. These low pumice concentrations are typical of most “pumiceous” layers throughout this interval and indicate significant reworking of pumiceous detritus and admixture with dacitic and other intermediate-composition lavas. Pumices at the 1642- to 1647-ft depth contain phenocrysts of sanidine and quartz; those at the 1717- to 1722-ft depth contain plagioclase and amphibole. Although the pumices are vitric and largely unaltered, many contain clay (smectite) in vesicles. Smectite concentrations are minor and comprise only 1–3% of the bulk sample (rows 7 and 8, Table 3.1-2). Puye pumice separates were also analyzed; these too have very little clay alteration (from no clay to only ~10%, Table 3.1-3). Puye samples from below the 1518-ft depth also differ from those above in their lower strontium content (~250–300 ppm versus ~420–500 ppm; Table 3.1-1) and higher rubidium content (~125–135 ppm versus 60–80 ppm). The rubidium-strontium composition of the Puye samples at CdV-R-15-3 is compared with Puye samples from other drill holes in Figure 3.1-1. Although the upper fanglomerates at CdV-R-15-3 are very similar to upper Puye fanglomerates from other drill holes, the lower pumiceous samples are significantly different from the other pumiceous Puye samples with the exception of a high-silica tuff that was sampled near TD at R-25. The strontium and rubidium relations summarized in Figure 3.1-1 indicate that siliceous tephras within the pumiceous Puye at CdV-R-15-3 may be similar to those at R-25 and distinct from those in pumiceous Puye from the central LANL site drill holes (R-19, R-15).

The heterogeneous and locally pumiceous Puye fanglomerates in CdV-R-15-3 have numerous horizons of high porosity. Both the caliper log and the borehole video show the borehole wall to be very irregular in this interval; the borehole video provides evidence of many coarse clasts up to, and exceeding, 30 cm in size. The borehole in this interval deviates around many cobbles of 15 cm or greater diameter that protrude from the borehole wall. Clast sizes in recovered cuttings are typically larger at the interval of 1518 ft to TD than the clast sizes at the 997- to 1518-ft interval. The FMI geophysical logging results indicate abundant coarse cobbles up to and exceeding 30 cm in size, but also reveal numerous beds of sandy detritus up to a few feet thick. The FMI results also indicate generally higher electrical conductivity and numerous intervals of relatively high free-fluid porosity (~0.3–0.4 ft^3/ft^3) in this interval. The dip of bedding revealed in the FMI log is generally small and distributed with no consistent suggestion of structure, except for the interval at 1545–1553 ft which has a consistent 5–10° west dip, and the interval at 1566–1582 ft which has a consistent 5–10° north to northwest dip. Screen #6 (1637.9–1644.8 ft) is in a zone of typically high porosity for this interval and is situated across the horizon where thorium and potassium begin to diminish into the lower Puye section.

Table 3.1-1
XRF Analyses of Samples from CdV-R-15-3

	Sample and Depth[a]									
	(1) CdV-R-15 617–622	(2) CdV-R-15 967–972	(3) CdV-R-15 972–977	(4) CdV-R-15 982–987	(5) CdV-R-15 1002–1007	(6) CdV-R-15 1272–1277	(7) CdV-R-15 1347–1352	(8) CdV-R-15 1447–1452	(9) CdV-R-15 1642–1647	(10) CdV-R-15 1717–1722
Lithology	Otowi	Dacitic lava	Dacitic lava	Basaltic lava	Basaltic lava	Puye	Puye	Puye	Puye	Puye
Size analyzed	< 1 mm	1–2 mm	Hand-picked	Hand-picked	Hand-picked	2–4 mm	2–4 mm	0.25–1 mm	2–4 mm	2–4 mm
SiO_2%	77.2	66.9	67.4	53.4	52.8	67.0	67.5	69.4	69.8	69.3
TiO_2%	0.11	0.53	0.47	1.35	1.38	0.51	0.49	0.39	0.33	0.40
Al_2O_3%	10.95	15.24	15.11	15.67	15.59	14.65	14.77	14.76	14.01	14.22
Fe_2O_3%	1.28	3.77	3.73	8.10	8.30	3.86	3.70	2.68	2.61	2.81
MnO%	0.05	0.05	0.05	0.14	0.14	0.07	0.06	0.05	0.06	0.06
MgO%	0.15	1.30	1.37	5.91	6.05	1.66	1.54	0.97	1.03	1.18
CaO%	0.44	3.13	3.30	7.30	7.40	3.30	3.18	2.74	1.99	2.16
Na_2O%	3.73	3.81	3.81	3.86	4.04	3.79	3.70	3.70	3.85	3.76
K_2O%	3.67	3.16	3.20	2.26	2.35	3.24	3.31	3.53	3.93	3.96
P_2O_5%	0.02	0.18	0.17	0.61	0.65	0.22	0.20	0.13	0.08	0.11
LOI%[b]	1.06	0.73	0.40	0.44	0.17	0.83	0.56	0.85	1.28	0.81
Total %	98.7	98.8	99.0	99.0	98.9	99.1	99.0	99.2	99.0	98.7
Vanadium (ppm)	< 10	64	56	125	146	65	55	30	19	40
Chromium (ppm)	< 8	15	31	172	172	16	23	< 8	< 8	20
Nickel (ppm)	< 11	21	18	116	118	22	19	< 12	28	22
Zinc (ppm)	57	47	43	75	72	50	52	41	47	31
Rubidium (ppm)	136	58	65	40	40	66	61	79	135	124
Strontium (ppm)	48	445	439	873	864	497	465	423	256	296
Yttrium (ppm)	46	35	24	42	32	15	18	15	33	27
Zirconium (ppm)	127	187	176	216	227	175	173	189	163	171
Niobium (ppm)	57	18	10	36	30	31	17	18	51	40
Barium (ppm)	116	1370	1331	1321	1263	1236	1340	1294	699	797

Note: Values reported in percent or parts per million by weight. Analytical errors (2σ) are SiO_2, 0.7; TiO_2, 0.01; Al_2O_3, 0.2; Fe_2O_3, 0.06; MnO, 0.01; MgO, 0.08; CaO, 0.1; Na_2O, 0.1; K_2O, 0.05; P_2O_5, 0.01; vanadium, 10; chromium, 8; nickel, 10; zinc, 12; rubidium, 5; strontium, 25; yttrium, 6; zirconium, 30; niobium, 7; and barium, 50.

[a] **Number ranges indicate depth ranges of cuttings in ft.**

[b] **LOI = loss on ignition.**

Table 3.1-2

XRD Analyses of Sediments from CdV-R-15-3 (Minerals in Weight %)

Sample Depth (ft), Unit or Lithology, and Size-Fraction Analyzed	Smectite	Tridymite	Cristobalite	Quartz	Alkali Feldspar	Plagioclase	Glass	Hematite	Biotite	Hornblende	Total
(1) CdV-R-15-3 617–622 (Otowi, < 1 mm)	—	—	0.6	23.5	8.9	19.0	45.0	—	—	—	97.1
(2) CdV-R-15-3 967–972 (dacite, 1–2 mm)	2.0	9.5	8.6	1.0	15.0	41.6	16.6	—	0.8	—	95.1
(3) CdV-R-15-3 972–977 (dacite, hand-picked)	4.0	14.1	9.7	0.1	18.9	40.4	7.6	—	0.4	—	95.2
(4) CdV-R-15-3 1272–1277 (Puye, 2–4 mm)	—	6.3	6.1	0.1	10.2	38.8	36.0	1.0	1.2	—	99.7
(5) CdV-R-15-3 1347–1352 (Puye, 2–4 mm)	—	7.0	8.3	0.2	12.9	43.9	25.6	0.6	1.2	—	99.8
(6) CdV-R-15-3 1447–1452 (Puye, 0.25–1 mm)	—	7.0	5.9	1.0	10.6	38.1	36.9	0.4	0.2	—	100.2
(7) CdV-R-15-3 1642–1647 (Puye, 2–4 mm)	1.0	6.2	7.6	1.6	13.9	28.5	37.5	0.8	2.6	0.1	99.8
(8) CdV-R-15-3 1717–1722 (Puye, 2–4 mm)	3.0	7.9	8.3	1.1	16.4	34.0	26.2	0.8	1.5	0.1	99.4

Note: Analytical errors (2σ) are ~5% of the amount reported for abundances > 10% and ~10% of the amount reported for abundances < 10%; dashes indicate that the phase was not detected; detection limits are ~0.1%.

Table 3.1-3

XRD Analyses of Pumices Separated from CdV-R-15-3 (Minerals in Weight %)

Sample Depth (ft) from Which Pumice Separate Was Obtained	Smectite	Tridymite	Cristobalite	Quartz	Alkali Feldspar	Plagioclase	Glass	Hematite	Biotite	Hornblende	Total
(1) CdV-R-15-3 1642–1647 (pumice #1)[a]	—	—	—	0.7	1.2	2.4	95.7	—	—	—	100
(2) CdV-R-15-3 1642–1647 (pumice #2)[a]	1.8	—	0.2	0.6	1.0	32.3	61.7	—	2.3	—	100
(3) CdV-R-15-3 1717–1722 (pumice)	9.7	—	—	0.4	1.2	3.0	85.4	—	—	0.2	100

Note: Analytical errors (2σ) are ~5% of the amount reported for abundances > 10% and ~10% of the amount reported for abundances < 10%; dashes indicate that the phase was not detected; detection limits are ~0.1%.

[a] Two different pumices were selected at 1642–1647 ft.

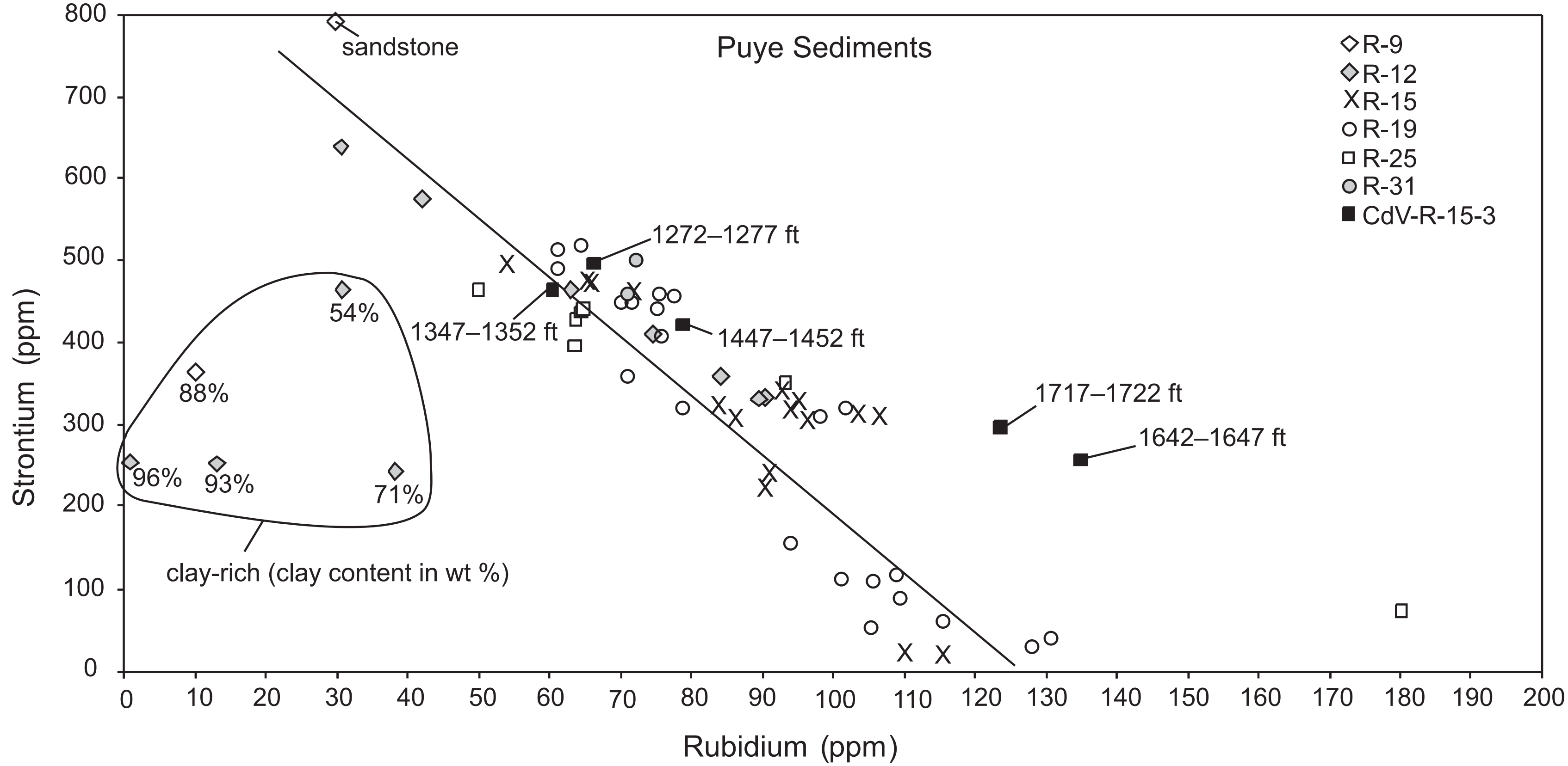


Figure 3.1-1. Plot of strontium versus rubidium for Puye Formation samples from analyzed R-series drill holes
(Diagonal line shows the general trend of increasing rubidium and decreasing strontium with depth within the Puye Formation of the central LANL site. Deeper samples from CdV-R-15-3 and R-25 tend toward higher rubidium composition. The circled low-rubidium samples from R-9 and R-12 are thoroughly clay-altered pumiceous deposits; rubidium loss is associated with the alteration process.)

3.2 Borehole Geophysics

This section describes the borehole geophysical logging measurements that were acquired during and after the completion of drilling activities.

The primary purpose of the open-hole geophysical logging was to characterize the hydrology and geology of the formation surrounding the borehole by measuring the following items, nearly continuously, along the length of the well:

- the water-filled porosity at different depths of investigation, both in the vadose and saturated zones;
- the effective water-filled porosity and pore size distribution, from which an estimate of hydraulic conductivity is made;
- the bulk density and photoelectric (Pe) factor—the former is sensitive to total porosity (air- and water-filled) and the latter is sensitive to the average atomic number of elements in the formation;
- the spectral natural gamma-ray (GR) activity, including potassium, thorium, and uranium concentrations, for identifying changes in lithology and geologic contacts;
- the bedding orientation and geologic texture; and
- the vertical flow rate and the temperature profile of the borehole fluid.

3.2.1 Description of Borehole Logging Activities

Borehole geophysical data came from two sources: (1) Laboratory and support subcontractor personnel who produced borehole video (BV) and GR surveys using Laboratory geophysical logging equipment; and (2) Schlumberger, Inc., personnel who produced a suite of borehole geophysical logs. Table 3.2-1 lists the borehole video and geophysical surveys that were obtained from each source. Borehole geophysical surveys were obtained from the open borehole which extended from the base of drill casing, at about 20 ft bgs, to near the total depth of the well, which was found to be at 1678 ft bgs at the time of the Schlumberger borehole surveys.

The well was logged on six separate occasions:

1. March 25, 2000, by the resident geological contractor, with a 4-in. side-view video camera, the 1.75-in. slim-hole video camera, and the gamma-ray probe, from ground surface to ~700 ft, prior to completion when the borehole was predominantly open-hole and drilled to a depth of 722 ft—to evaluate hole conditions and the presence of visible moisture from a possible perched aquifer on the borehole wall;
2. April 27, 2000, by the resident geological contractor, with a 4-in. side-view video camera and a natural gamma-ray probe, just prior to completion and taken from ~500 to 1680 ft, in predominantly open-hole—to evaluate changes in hole conditions and the static water level;
3. April 28–29, 2000, by Schlumberger personnel, with a suite of advanced wireline logging tools from varying top depths to ~1680 ft, again when the borehole was predominantly open-hole—to evaluate formation hydrologic and geologic properties as well as assess the borehole for well screen placement;
4. May 1, 2000, by the resident geological contractor, with a 4-in. side-view video camera from ground surface to 1680 ft, just after the borehole was completed with 5-in. stainless-steel casing and well screens with bentonite-sand annular fill—to evaluate the impact of partially obscuring screens 3 and 5 with bentonite-rich annular fill;

5. July 27, 2000, by the resident geological contractor, with a 4-in. side-view video camera from ground surface to ~1680 ft—to evaluate yield from screened intervals; and
6. August 10, 2000, by the resident geological contractor, with a 1.75-in. slim-hole video camera and a natural gamma-ray probe from ground surface to ~1679 ft—taken and reviewed after well development for placement of the Westbay sampling ports.

These services were run at a number of different times and in different borehole conditions and, in some cases, in combination with each other. Table 3.2-1 summarizes the geophysical logging runs performed in CdV-R-15-3.

Table 3.2-1
Logging Services, Their Combined Tool Runs, and Intervals Logged

Date of Logging	Borehole Status	Operator of Geophysical Services	Tool 1	Tool 2	Tool 3	Depth Interval (ft)
March 25, 2000	Surface casing to 20 ft; open-hole to 722 ft	Resident geological contractor	BV	GR	—	0–700
April 27, 2000	0–20 ft: 18-in. casing 20–1722 ft: open-hole 1246 ft: borehole water level	LANL/resident geological contractor	GR GR BV, 1.75 in.	—	—	575–1680 484–1670 0–1680
April 28, 2000	Same as above	Schlumberger	HNGS	APS[a]	—	T1: 132–1655 T2: 132–1668
April 28, 2000	Same as above	Schlumberger	GR	CMR[b]	—	T1: 72–1655 T2: 72–1670
April 28, 2000	Same as above	Schlumberger	GR	LOT	AITH[c]	T1: 47–1650 T2: 76–1670 T3: 68–1682
April 28, 2000	Same as above	Schlumberger	GR	GPIT[d]	FMI	T1: 50–1653 T2: 50–1678 T3: 1246–1678
April 28, 2000	Same as above	Schlumberger	GR	PTS[e]	FBS	T1: 990–1666 T2: 1000–1675 T3: 1000–1675
May 1, 2000	0–20 ft: 18-in. steel casing 20–1682 ft: 5-in. steel casing	Resident geological contractor	BV	—	—	0–1680
July 27, 2000	0–20 ft: 18-in. steel casing 20–1682 ft: 5-in. steel casing	Resident geological contractor	BV, 4 in.	—	—	0–1680
August 10, 2000	0–20 ft: 18-in. steel casing 20–1682 ft: 5-in. steel casing	Resident geological contractor	BV, 1.75 in. GR	—	—	0–1673 0–1660

[a] APS = accelerator porosity sonde.

[b] CMR = combinable magnetic resonance.

[c] AITH = array induction tool, version H.

[d] GPIT = general purpose inclinometer tool.

[e] PTS = pressure temperature sonde.

Preliminary results of these measurements were generated in the logging truck at the time the geophysical services were performed, and they are documented in field logs provided on-site. However, the measurements presented in the field results are not corrected for borehole conditions and are provided as separate, individual logs.

The field results from the advanced wireline logging suite were processed at the Schlumberger data processing center in Englewood, Colorado, to (1) correct the measurements, as much as possible, for borehole environmental conditions; (2) perform an integrated analysis of the log measurements so that they were all coherent; and (3) combine the logs in a single presentation, enabling easy integrated interpretation. The reprocessed log results provide better quantitative property estimates, which are consistent for all applicable measurements, as well as estimates of properties that otherwise could not be reliably estimated from single measurements alone (e.g., total air- and water-filled porosity).

Overall, most of the geophysical log measurements from the CdV-R-15-3 well provided results that were consistent with each other, and most provided valuable information about hydrologic and geologic conditions surrounding the borehole. However, the well does contain a large number of severe washouts in which the quality of many measurements was compromised; in particular, the ability to measure true formation parameters was poor in the washout zones.

This information, along with the Laboratory's video and GR logs, was used to design the well completion: the placement and length of screens

3.2.2 Borehole Geophysical Methods

The geophysical log suite that was performed by Schlumberger employed advanced wireline logging technology using neutron emission and detection, natural gamma-ray spectroscopy, gamma-ray emission and detection, electromagnetic induction imaging, nuclear magnetic resonance imaging, high-resolution electrical imaging, a high-resolution temperature gauge, and a borehole fluid flow meter. Logging tools that require pad contact with the borehole wall and those that measure formation porosity were adversely affected by the numerous large washouts, especially at the bottom of the borehole, below 1500 ft. Additionally, several of the tools require water in the borehole to operate. Therefore, these provided measurement data only below the water level.

3.2.2.1 Borehole Video (BV; Laboratory Tool)

The video survey of the uncased borehole provided visual images of the borehole wall above and below the water level. Borehole video logs were made before and after geophysical logging, and they provided visual references for locations and relative size of borehole washouts, as well as locations of potential geologic contacts and potential perched water zones (the latter from water on the borehole wall). Video below the water table was hindered by water turbidity and percolating gas bubbles. Information from the video survey, in addition to the geophysical logs, was used to help select the lengths and placement of well screens.

3.2.2.2 Gross Gamma Ray (GR; Laboratory Tool)

The GR survey employs a scintillation detector to measure the gross gamma radiation activity of the formation; the information is used for determining lithology and for depth correlation between different geophysical surveys. Naturally occurring gamma radiation comes from the decay of potassium plus the uranium and thorium decay series. Typically, these elements occur in higher concentrations within clay minerals; however, at the Laboratory, GR is most affected by differences in unaltered volcanic lithology. The gross gamma signatures of each formation are also used for depth correlation between geophysical logging runs to ensure proper depth profiles for each geophysical log.

3.2.2.3 Hostile Environment Gamma-Ray Sonde (HNGS; Schlumberger Tool)

The HNGS uses two bismuth germanate scintillation detectors to measure the natural gamma radiation of the formation. The HNGS makes measurements that are similar to the NGR tool, but the HNGS is capable of gamma-ray energy discrimination. The HNGS uses five-window spectroscopy to resolve the detected spectrum into the three most common components of the naturally occurring radiation: potassium, thorium, and uranium. The high-energy part of the spectrum is divided into three energy windows, each covering a characteristic peak of the three radioactivity series. The concentration of each component is determined from the count rates in each window. Because the high-energy region contains only 10% of the total spectrum count rates, the measurements are subject to large statistical variations, even using a low logging speed. The results are considerably improved by including the contribution from the low-energy part of the spectrum.

Filtering techniques are used to further reduce the statistical noise by comparing and averaging counts at a certain depth with counts sampled just before and after. The final outputs are the total gamma ray, a uranium-free gamma-ray measurement, and the concentrations of potassium, thorium, and uranium. The radius of investigation depends upon several factors: hole size, mud density, formation bulk density (denser formations display a slightly lower radioactivity), and the energy of the gamma rays (a higher energy gamma ray can reach the detector from deeper in the formation).

3.2.2.4 Accelerator Porosity Sonde (APS; Schlumberger Tool)

The APS measures volumetric water content at several depths of investigation beyond the casing and is used to evaluate moist/porous zones and voids in annular fill. The APS measures the presence of hydrogen atoms in a formation by bombarding it with a large flux of high-energy neutrons from an electronic generator and measuring the response. The electronic neutron source generates 14-MeV neutrons in a pulsed mode at a flux rate of approximately 3×10^8 neutrons per second. This system employs four epithermal neutron detectors and one thermal neutron detector that make several lithology- and borehole-independent measurements of formation moisture content or saturated porosity at different depths of investigation, depending upon source-detector spacing. The maximum depth of investigation is approximately 30 cm (12 in.) and the vertical resolution is approximately 45 cm (18 in.).

The tool provides another moisture measurement based on the time it takes for neutrons to decelerate through nuclear interactions. Two epithermal detectors measure the decay of epithermal neutrons that occurs subsequent to a neutron pulse. The decay rate is a function of the hydrogen concentration; the more hydrogen, the faster the decay. This tool function has a vertical resolution of approximately 7.5 cm (3 in.), and the depth of investigation is approximately 5 cm (2 in.).

A thermal neutron detector measures the decay rate of thermal neutrons after the neutron pulse and is used to calculate a measurement of formation sigma (S)—the macroscopic thermal neutron absorption cross-section. Sigma is a function of the types and quantities of thermal neutron absorbers present within the formation. The larger sigma is, the faster the decay of the thermal neutron population. Sigma is typically measured in capture units (cu), a unit related to the mass-normalized thermal neutron cross-section. Quartz has a sigma of about 4 cu; fresh water has one of 22 cu. A comparison of sigma and epithermal neutron porosity can differentiate zones within the formation that contain higher concentrations of thermal neutron absorbers, independent of moisture.

The APS can be run in open or cased holes, water- or air-filled.

3.2.2.5 Combinable Magnetic Resonance (CMR; Schlumberger Tool)

Nuclear magnetic resonance (NMR) data are obtained for determining the porosity, pore-size distribution, and in situ hydraulic conductivity properties of the formations. The CMR tool makes pulse-echo nuclear magnetic resonance measurements that are sensitive to the hydrogen nuclei (protons) contained in the pore space of the formation. These measurements contain information relating to both pore water volume and pore size. The pore size information can be used to partition the formation porosity into bound and free fluid volumes. This information can, in turn, be used to estimate formation hydraulic conductivity and water productivity. The pore size information can also be used to extrapolate relative grain size. The pore size information is unique to NMR logging devices.

In the unsaturated zone, the CMR tool provides a volumetric moisture content of the formation, independent of lithology, and provides an estimate of the amount of water that binds to the pore walls (e.g., capillary-bound vs. producible water). This tool has a very shallow lateral depth of investigation (approximately 1 in.) and a 6-in. vertical resolution. It requires good contact between the tool's sensor pad and the borehole wall. Therefore, borehole washouts yield bad data.

3.2.2.6 Triple Detector Lithodensity Tool (LDT; Schlumberger Tool)

The LDT provides information about density and porosity in the unsaturated zone, and about porosity in the saturated zone. The LDT is a gamma-gamma density log that is used primarily to provide a measure of formation electron density. A 1.5-Ci cesium-137 gamma source is used to provide the excitation energy for the tool, which is calibrated to provide measurements in an air- or liquid-filled open hole, and in an uncemented steel casing. In addition to providing density measurements, the tool also measures the photoelectric absorption index of the formation in open boreholes.

Photoelectric absorption is a measure of the average atomic number of the formation which corresponds to formation chemistry and lithology. The electron density measurement is converted to formation bulk density which corresponds primarily to porosity and secondarily to rock matrix and pore fluid.

In the unsaturated zone, the LDT will provide a continuous log of formation porosity (liquid- and air-filled porosity). This measurement requires an estimation of formation grain density to provide accurate porosity estimates. The porosity estimate from the LDT is used with moisture content data (from the CMR and neutron surveys) to provide a continuous log of water saturation. The LDT has a 2.5-in. depth of investigation and a 6-in. vertical resolution.

3.2.2.7 Array Induction Tool, Version H (AITH; Schlumberger Tool)

The AITH is a focused electrical induction probe that measures electrical conductivity/resistivity at five depths of investigation: 10, 20, 30, 60, and 90 in., with a vertical resolution of 1, 2, and 4 ft.

From these measurements, the AITH provides quantitative estimates of

- true bulk formation resistivity—formation resistivity is a function of water content, water salinity, and clay content.
- drilling fluid invasion—for instances in which the borehole fluid and formation fluid possess contrasting conductivity values, the depth of invasion of filtrate can be mapped and the zones with higher permeability can be identified.

The results are also useful for stratigraphic correlation.

3.2.2.8 General Purpose Inclinometer Tool (GPIT; Schlumberger Tool)

The GPIT uses a three-axis magnetometer and a three-axis accelerometer to accurately define the orientation of the axis with respect to the earth's gravity (G) and magnetic field norm (F). Since both vectors (G and F) are well defined within the earth's system, a relation can be established between the tool system and that of the earth. The logging truck computer uses the three components of the magnetometer and accelerometer to calculate deviation, azimuth, and relative bearing. The GPIT cannot be run in steel casing since it employs a magnetometer. When the FMI is run, the GPIT is housed in the FMI.

3.2.2.9 Formation Microimager (FMI; Schlumberger Tool)

The FMI tool collects resistivity data from multiple micro-pads located on four caliper arms. The orientation of the tool in the borehole is recorded, enabling the resistivity data to be “imaged” to show a likeness of the borehole wall at the caliper pad and the data to be processed to calculate formation dip angles. The FMI tool provides images that are almost totally insensitive to borehole conditions and offers quantitative information for clast size, bedding structure, and fracture analysis.

3.2.2.10 Pressure Temperature Sonde (PTS; Schlumberger Tool)

The PTS measures borehole temperature and pressure (if run with pressure gauge) with high precision. In addition, the temperature gradient is computed. The temperature versus depth profile can provide information about waters of different temperature entering/exiting the borehole. Only the temperature measurements were made in CdV-R-15-3. The data quality appears to be very good.

3.2.2.11 Full Bore Spinner (FBS; Schlumberger Tool)

The FBS makes continuous and stationary measurements of the borehole fluid flow rate by measuring the rotation of a spinner device in cycles per second. When up and down passes are made and the tool speed is known, an absolute fluid flow rate can be estimated. In CdV-R-15-3, both continuous up and down passes and stationary measurements were made. The results are erratic and quite variable. It is suspected that the data quality is affected by gas bubbles percolating from the borehole wall through much of the water-filled hole.

3.2.3 Results

The primary objective of the geophysical investigations was the identification of water-bearing formations intersected by CdV-R-15-3. Secondary objectives included evaluating the geophysical data for definition of stratigraphic contacts; acquiring additional geochemical data about the relative potassium, uranium, and thorium content of formations; and examining the conformation of the well.

The following salient features were part of the geophysical investigation:

- Neutron logging (the CMR tool and APS readings), with the LDT formation porosity readings, were used to identify six potentially productive regions in the well. The six well screens were placed adjacent to, or at the bottom of, these regions.
- The gamma-ray probe provided corroborating data defining the Qbt 3/Qbt 2 and the Qbt 2/Qbt 1v contacts in the Tshirege Member; the HNGS scintillation detector was particularly useful in identifying four subdivisions of the Puye Formation fanglomerate.
- The HNGS and the total GR probe provided geochemical information throughout the borehole. The nature of information varied, depending upon the formation. In the Bandelier Tuff, overall sensitivity of the GR tool helped to define subdivisions of the Bandelier and to identify the Cerro Toledo interval (Figure 3.0-4). In the Puye Formation, the HNGS could identify spectral gamma potassium-uranium-thorium subdivisions not seen with any other tool.
- The Pleistocene Cerro Toledo was determined to be much thicker (220 ft) than the thickness predicted by the 3-D geologic model. The borehole video log provided a record of clast sizes

through the interval. This new information will be used in the revision of the 3-D geologic model.

- Borehole caliper logging indicated significant washout from ~120 to 154 ft; the APS measurements suggested numerous washouts from 1496 to1680 ft.
- The GPIT indicated that the borehole deviated little from vertical for the interval above 800 ft; from 800 ft to TD, CdV-R-15-3 deviated approximately 38 ft to the west and 6 ft to the south.

The Schlumberger geophysical logging runs are described in more detail in a file entitled `CdV-geo.pdf`, which can be found on the CD attached to the inside back cover of this report. On that same CD are PDF versions of the well's geophysical log montage and the ELAN log.

4.0 HYDROLOGY

Hydrologic testing and observations were concentrated on the saturated zones; unsaturated zones and cuttings were not tested.

4.1 Groundwater Occurrence

Prior to drilling, three saturated zones were projected to occur at CdV-R15-3: two perched water bodies and the regional zone of saturation. Perched saturation was expected in the lower part of the Otowi Member of the Bandelier Tuff (Guaje Pumice Bed) and the Cerros del Rio basalt, in descending order. Regional saturation was predicted to occur in the Puye Formation fanglomerate.

Possible perched saturation was first encountered at a depth of 611 ft in the upper part of the Otowi Member, Bandelier Tuff. At a borehole depth of 622 ft, water-level depth was again monitored (through the drill rods with an electric probe) and found to be 602 ft. This saturation may have been either ephemeral or due to water introduced during drilling. No saturation was detected in the Guaje Pumice Bed.

Other possible perched zones were observed by the site geologist or on the borehole video. These were at 708 ft (Otowi), 920 ft (Puye), 960–990 ft (bottom of Puye/top of Cerros del Rio basalt), and 1242–1249 ft (Puye). The geophysical data indicated zones of potential saturation at 600–620 ft (Otowi), 800–820 ft (top of Puye), and 965–990 ft (top of Cerros del Rio basalt).

Regional saturation was found to occur in the Puye Formation fanglomerate as predicted. The top of such saturation was determined to be at a depth of 1245 ft. This is 74 ft deeper than anticipated from the regional water-level map.

It should be noted that it was difficult to determine water levels throughout the installation of CdV-R-15-3. One cause was drilling fluids which clung to the inside walls of the rods and fouled the electric water-level probe used for such measurements. In addition, foam from the drilling fluids hindered attempts to locate the top of the borehole's water column by means of the video camera.

During the first three rounds of quarterly sampling (through July 2001), water was not detected in the uppermost three screens: screen #1 (617.7–624.5 ft), screen #2 (800.8–807.8 ft), or screen #3 (964.8–980.9 ft).

4.2 Groundwater Movement

Groundwater movement is usually characterized in terms of directions and rates of horizontal and vertical flow. Data for evaluating horizontal flow direction are not normally provided by a single well. Either a water-level map or the water levels from at least three wells that form the corners of a triangle is required. However, vertical flow direction can be determined from vertical head distribution or static water levels at various borehole depths. Hydraulic conductivity obtained from field tests provides an indication of potential flow rates.

Vertical flow direction could not be evaluated during drilling because static water levels were not obtained at different borehole depths. This was due to the difficulty of determining water level as described above. The two head measurements made during hydrologic testing suggest a slight upward gradient. However, heads measured by transducers in the Westbay system confirm a downward gradient, as expected in this recharge area (Appendix D).

Straddle-packer/injection tests were conducted in the field for two of the screened intervals: screen #5 (the middle of three screens in the regional zone of saturation, at a depth of 1348.4–1355.3 ft) and screen #6 (the lowermost of three screens in the regional zone of saturation in the Puye Formation, at a depth of 1637.9–1644.8 ft). Screen #3 (964.8–980.9 ft) was not tested because there was too little water for the transducer to register. No test was conducted for screen #4 (1235.1–1278.9 ft) because it straddles the water table (analytical methods require the screen to be below the water table).

In the case of the other screens, water was injected at a constant rate into the target interval which was isolated from the rest of the well during the test by two packers, one placed above and one placed below the screen. Injection rate was monitored by a flow meter installed between the water supply and the Bean pump on the UDR rig. The preliminary results for the tests of screen #5 (1348.4–1355.3 ft) and screen #6 (1637.9–1644.8 ft) are given in Table 4.2-1. A separate report, with final results and complete details regarding these tests, is in preparation.

Table 4.2-1
Summary of Data for Straddle-Packer/Injection Testing of Saturated Materials at CdV-R-15-3

Screen	Static Water Level Depth (ft)	Test Duration (min)[a]	Hydraulic Conductivity (ft/d)	Analytical Method
5	1239	30	0.25	Theis (1935, 66784)
6	1233	600	0.10	Bouwer and Rice (1976, 64056)

[a] Water was not continuously injected; rather, rods connected to packers were filled with water to a level approximately 200 ft above the transducer.

5.0 HYDROGEOCHEMISTRY

Well CdV-R-15-3 was sited and designed to evaluate the presence and mobility of anthropogenic constituents, particularly HE, in perched and regional groundwaters downgradient from TA-16. The well is not a hydrologic characterization well; instead, it is designed to (1) bound the extent of contamination presumed to derive from the 260 outfall in the perched and regional aquifers; (2) collect data to be used in the CMS for evaluating contaminant impact on potential receptors; and (3) determine if there is a threat to human health and the environment associated with groundwater contamination from PRS 16-021(c)-99. Thus, the emphasis during drilling and installation of the well was on cost-effective drilling and installation of a Westbay sampling system, rather than on hydrogeochemical characterization.

The sections below report briefly on the hydrogeochemical characterization that did occur during the drilling of CdV-R-15-3. Seven discrete water samples were selected for analysis during drilling. Five of these samples were taken primarily to determine if individual perched zones or the regional aquifer contained HE constituents. Two of these samples were taken primarily to evaluate if drilling additives or bentonite were affecting water chemistry.

5.1 HE Chemistry of Groundwater Samples

Six groundwater zones were sampled during drilling at CdV-R-15-3. The samples were collected at depths of 622, 1137, 1250, 1497, 1620, and 1650 ft, and were analyzed for relevant suites of constituents, including HE, geochemical parameters, and total organic carbon (TOC). Samples RE15-00-0093 and RE15-00-0094 were split samples obtained from the aliquot collected at 622 feet. They were sent to two different laboratories. Samples were not filtered prior to analysis. The HE samples were collected to determine if HE were present in the borehole. The two geochemistry and TOC samples were taken for evaluating the possibility that drilling additives or bentonite, which were hypothesized to be present adjacent to screens #4, #5, and #6, were affecting water chemistry. Table 5.1-1 presents a summary of the groundwater samples that were collected during the drilling of CdV-R-15-3.

Additional groundwater samples will be collected quarterly and will be reported on in the PRS 16-021(c)-99 CMS report.

Table 5.1-1
Summary of Groundwater Samples Collected During Drilling of CdV-R-15-3

Sample ID	Request Number	Depth of Water Collection (ft)	Date Collected	HE	TOC	Geochemistry
RE15-00-0093	6595R	622	3/23/00	X[a]	—	—
RE15-00-0094	6594R[b]	622	3/23/00	X	—	—
RE15-00-0096	7310R	1137	3/31/00	X	—	—
RE15-00-0100	6691R	1497	4/5/00	X	—	—
RE15-00-0108	6775R	1620	4/24/00	X	—	—
RE15-00-0112	7250R	1250	7/31/00	—	X	X
RE15-00- 0113	7254R	1650	8/3/00	—	X	X

[a] X indicates that an analysis was performed.

[b] Sample RE15-00-0094 was the only sample sent off-site for analysis. All other samples were analyzed at laboratories within LANL and are therefore considered screening samples.

5.2 Methods

Groundwater samples for HE, TOC, and geochemical analysis were collected from the cyclone during drilling. Temperature, turbidity, pH, and specific conductance were determined on-site from an aliquot collected during field sampling. Field parameters are presented in Table 5.4-1. All samples collected in the field were stored at 4°C until they were analyzed.

Groundwater samples were analyzed using techniques specified in Environmental Protection Agency (EPA) method SW-846, including high-performance liquid chromatography (HPLC) for explosives; ion chromatography for anions such as chloride, bromide, fluoride, nitrate, phosphate, and sulfate; and graphite furnace atomic absorption (GFAA) and inductively coupled plasma emission spectroscopy (ICPES) for cations such as boron, calcium, potassium, lithium, magnesium, sodium, and silica. Bicarbonate was analyzed using titration methods.

Laboratory blanks were collected and analyzed in accordance with EPA and Laboratory procedures. The analytical precision for cations and anions was generally ±10%.

5.3 HE

Low levels of HE constituents 4-amino-2,6-dinitrotoluene (0.11 µg/l, qualified as estimated) and 2,6-dinitrotoluene (0.49 µg/l) were detected in sample RE15-00-0094. This sample was taken from the first potential perched zone encountered in CdV-R-15-3, which was located at a depth of ~610 ft. The HE levels are near the detection limits for the EPA analytical method used. These constituents were not detected in sample RE15-00-0093, the split sample pair to RE15-00-0094. Other water samples (see Table 5.1-1) that were analyzed for HE reported no detected HE constituents; however, the other samples were analyzed at an on-site laboratory with higher detection limits and lower data quality standards. It is likely that these detected compounds are actually false positives associated with the presence of EZ-MUD and other drilling fluids in the groundwater. Groundwater samples collected from wells drilled with EZ-MUD and other drilling fluids have shown a higher incidence of false positives for compounds such as dinitrotoluenes. Because of this problem with false positives, currently collected groundwater samples are analyzed by an additional, more sensitive method than the one used to analyze RE15-00-0094.

5.4 Quality of Groundwater Within the Puye Formation

Field-measured parameters for the borehole groundwater samples, including pH, temperature, specific conductance, and turbidity, are provided in Table 5.4-1. These parameters were measured at the time of sample collection, when the groundwater was in contact with the atmosphere.

Table 5.4-1
Field Parameters for Water Samples from CdV-R-15-3

Sample ID	Depth of Water Collection (ft)	Conductance (µS/cm)	pH	Temperature (°C)	Turbidity (NTU)[a]
RE15-00-0093	622	0.143	7.2	28.0	Off scale
RE15-00-0094	622	0.143	7.2	28.0	Off scale
RE15-00-0096	1137	0.409	7.7	18.2	Off scale
RE15-00-0100	1497	0.269	8.1	20.4	Off scale
RE15-00-0112	1250	0.099	6.1	18.3	4.1
RE15-00- 0113	1650	0.106	7.9	18.7	1.9

[a] NTU = nephelometric turbidity unit.

Groundwater from the regional aquifer at CdV-R-15-3 is a calcium-sodium-bicarbonate type, as shown in unfiltered samples collected at both 1250 and 1650 ft. The screening analytical results for the samples from 1250 ft and 1650 ft are shown in Table 5.4-2. TDS values are low (163.6 to 170.4 ppm) and similar to, or lower than, the TDS values of samples from the regional aquifer collected at R-25 (Broxton et al., in preparation). Most major cation and anion constituent abundances are similar to values measured in R-25, which was drilled using few if any drilling additives.

Concentrations of constituents that are indicative of bentonite interactions with groundwaters, such as sodium, sulfate, and TOC, are all low (11–12 ppm, 2.2–2.99 ppm, and .8–1.5 ppm, respectively) in the regional aquifer in CdV-R-15-3. These values are similar to those measured in the regional aquifer in boreholes drilled with minimal bentonite addition. They are also significantly lower than values measured in wells such as R-15 (Longmire et al. 2001, 70103). These results suggest that waters in the regional aquifer at CdV-R-15-3 have not had their chemistry significantly modified by interaction with bentonite.

Table 5.4-2
Hydrochemistry of Screening Samples from CdV-R-15-3

	1250-ft Depth	1650-ft Depth
Geologic Unit	Puye Formation	Puye Formation
Sample Treatment	Unfiltered	Unfiltered
Date Sampled	8/2/00	8/2/00
Boron (ppm)	< 0.01	< 0.01
Bromide (ppm)	< 0.02	< 0.02
Carbon (TIC[a]) (ppm)	14.1	14.4
Carbon (TOC) (ppm)	1.5	0.8
Calcium (ppm)	10.0	10.7
Chloride (ppm)	1.23	1.31
Fluoride (ppm)	0.06	0.04
HCO_3 (ppm)	68.8	71.8
Potassium	1.3	1.5
Lithium	< 0.01	< 0.01
Magnesium (ppm)	3.14	3.27
Sodium (ppm)	11.2	12.4
Nitrite (ppm)	< 0.02	< 0.02
Nitrate (ppm)	0.82	1.31
Oxalate (ppm)	< 0.02	< 0.02
pH (lab)	7.47	7.33
Phosphate (ppm)	< 0.05	< 0.05
Silica (ppm)	30.3	30.4
SiO_2 (ppm calc.)	64.8	65.1
Sulfate (ppm)	2.21	2.99
TDS (ppm)	163.6	170.4
Cation sum	1.278	1.381
Anion sum	1.225	1.300
Balance	0.0420	0.0604

[a] TIC = total inorganic carbon.

Note: Data in this table are screening level (samples were not sent to off-site laboratories; they were analyzed by LANL internally).

6.0 SURVEY ACTIVITIES

Well CdV-R-15-3 was geographically surveyed using a global positioning system (GPS) on November 2, 2000. A Trimble 4000 SSE dual-frequency base receiver was set up and initialized over control monument A1502 in TA-15 for conducting the real-time kinematic survey. Coordinate values for the control came from the 1992/1993 GPS survey establishing the LANL control network; the coordinate values are published in the *LANL Survey Monument Network Manual,* and the monuments are certified to have been placed in conformance to standards and specifications for Order 2-1 surveys or greater. The datum for the horizontal control network is the North American Datum of 1983 (NAD-83).

A Trimble 4000 SSE dual-frequency roving receiver collected satellite signals, as well as base-station signals, for the calculation of position. The roving receiver was used at the CdV-R-15-3 well, approximately 650 ft south of the control.

The receiver provided position data relative to the World Geodetic System (WGS) 1984 ellipsoid; algorithms within the survey controller transformed the WGS-84 position to the New Mexico State Plane coordinate system using the North American Datum of 1983 and seven transformation parameters. Elevation measurements are reported in feet and have been referred to the National Geodetic Vertical Datum of 1929 (see Table 6.0-1).

Table 6.0-1
Geodetic Data for CdV-R-15-3

Description	East	North	Elevation
Brass cap in CdV-R-15-3 pad	1623221.0	1762349.2	7258.9
Top of collar on WB casing	1623222.3	1762347.5	7260.9

7.0 WELL DESIGN, CONSTRUCTION, AND DEVELOPMENT

7.1 Well Design

Well CdV-R-15-3 was installed to enable the Laboratory’s ER Project to determine the extent of contamination in perched water zones and the regional aquifer. The well allows ER Project personnel to measure fluctuations in the depth to water within perched water zones and within the regional aquifer. The location and design also provide the means for monitoring the presence of dissolved HE constituents and their degradation products and for monitoring the movement of these contaminants away from Cañon de Valle and R-25.

The anticipated well design provided for five well screens: two in the unsaturated zone and three in the regional zone of saturation. After the open borehole video and geophysical logs were reviewed, a third screen in the unsaturated zone was added to the design. The well is equipped with a Westbay monitoring and sampling system. The design life of CdV-R-15-3 is 50 years.

7.2 Construction

The monitor well casing is 5-in. OD (0.247-in. wall), ASTM A 312 standard stainless-steel casing and stainless-steel pipe-based wire-wound screen. The screen slot size is 0.010 in. The six screened intervals in the well are separated by bentonite and cement grout seals. Well screens are sand-packed with silica sand. Three different gradations of sand pack were used: 20/40, 8/12, and 6/9. A diagram of the well’s construction is shown in Figure 7.2-1.

Screen locations were selected by reviewing video surveys of the open borehole, reviewing geologic logs from cuttings samples, and analyzing geophysical borehole logs. A technical review team of personnel from the Laboratory’s ER Project; Washington Group International/Program Management Company (WGI/PMC); John Shoemaker and Associates, Incorporated (JSAI); and Schlumberger met to review borehole videotapes, geophysical logs, and well construction details before selecting proposed locations for screened intervals. The proposed plan was provided to the Department of Energy and to the New Mexico Environment Department for review.

Well CdV-R15-3 contains six separate screened intervals along its total depth of 1675 ft. The screens are numbered in descending order from ground surface. Screens #1 through #3 were set at points opposite suspected perched water zones. Screen #4 is the longest screen (43.8 ft); it spans the surface of the regional water table. Screens #5 and #6 are set in middle and deep parts of the regional aquifer in the Puye Formation. A summary of screen-setting information is provided in Table 7.2-1.

Table 7.2-1
Summary of Well Screens for CdV-R-15-3

Screen	Depth Interval (ft)	Screen Length (ft)	Depth of Hydrogeologic Target (ft)	Sand-Pack Gradation	Hydrogeologic Target of Screen	Geologic Unit
1	617.7–624.5	6.81	600–620	20/40	Perched water zone	Otowi Member, Bandelier Tuff
2	800.8–807.8	6.92	750–800	20/40	Perched water zone	Contact of Guaje Pumice Bed and Puye Formation
3	964.8–980.9	26.13	965–997	20/40	Perched water zone	Cerros del Rio Basalt
4	1235.1–1278.9	43.80	1240–1250	8/12	Top of saturation in regional aquifer	Puye Formation
5	1348.4–1355.3	6.93	1340–1350	6/9	Permeable zone in regional aquifer	Puye Formation
6	1637.9–1644.8	6.90	1630–1640	8/12	Lower borehole in regional aquifer	Puye Formation

During well construction, the six screens were inadvertently placed 9 ft deeper than intended due to a tally error on well casing during construction. The shift resulted in two screens (#3 and #5) being partially covered with bentonite. All screens are still in communication with the targeted zones. Figure 7.2-1 shows backfill material depths based on wireline measurements made during completion.

On August 11, 2000, a natural gamma log of the cased hole was run with the Laboratory-owned logging trailer. A natural gamma log can distinguish between the filter pack and the bentonite because silica sand has a relatively low natural gamma emission and bentonite has a relatively high natural gamma emission. The log indicated that the lower 31% of screen #3 and the lower 34% of screen #5 are covered with bentonite. Sand filter pack materials are adjacent to the rest of the screens.

During the first three quarterly sampling events, no evidence of restricted flow through the partially covered screens or other effects on the well or the volume of samples was observed. In addition, the primary potential contaminants of concern are HE and most HE have a very low adsorption coefficient and remain in solution; therefore, the presence of bentonite should not affect potential HE-contaminant analyses.

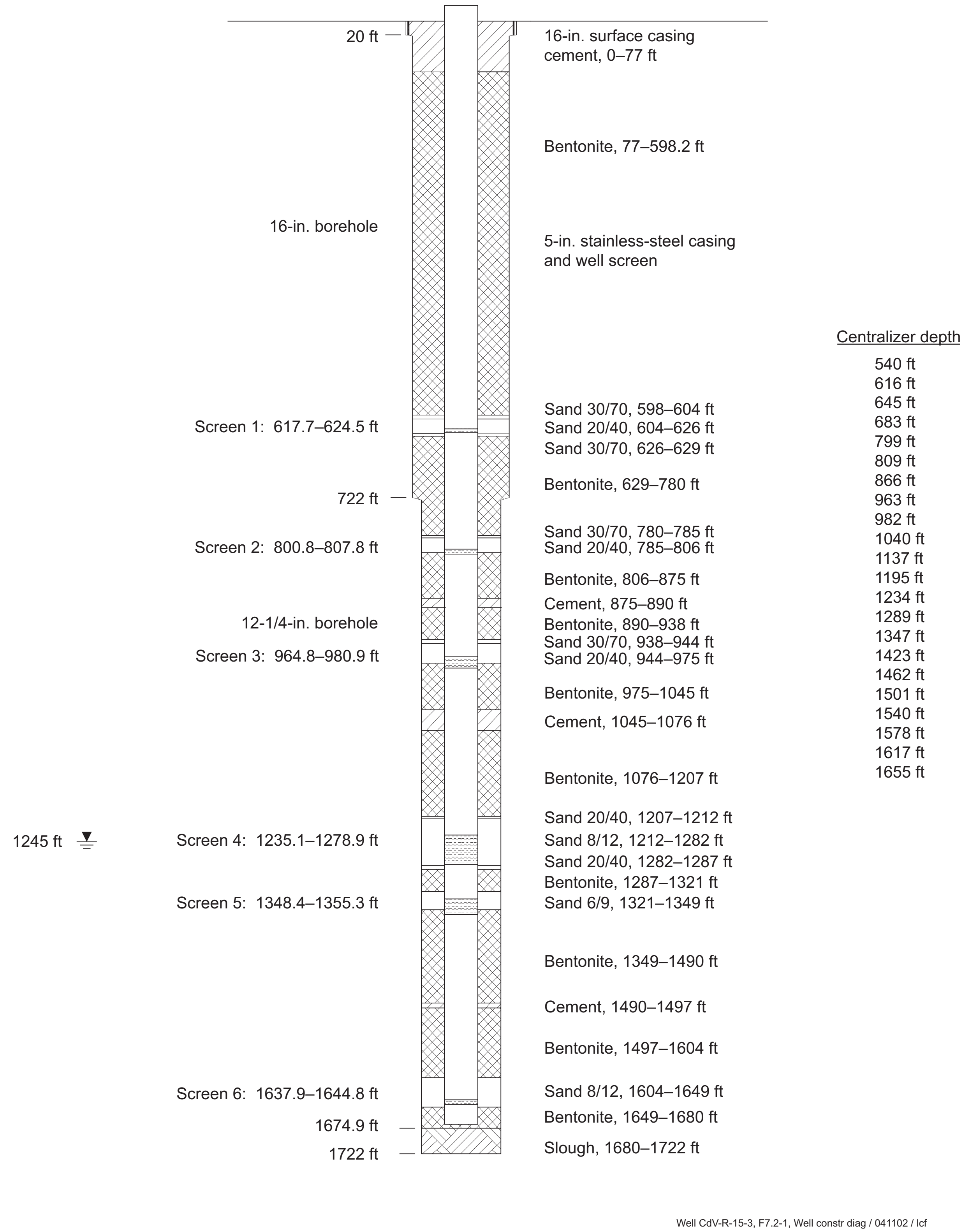


Figure 7.2-1. Well-construction diagram for CdV-R-15-3 (depth/thickness of annular fill material determined by wireline measurements)

7.3 Well Development

Development of CdV-R-15-3 was accomplished through a three-stage process: scrubbing, bailing, and zone-specific pumping.

Initial development consisted of scrubbing the inside of the casing and screens with a wire brush installed on drill pipe. After scrubbing, muddy fluid and settled solids were bailed from the well. The bailer was 28 ft long with an inside diameter of 3 in. and a capacity of approximately 10 gal. Bailing was performed from July 29 to July 30, 2000. A total of 740 gal. of water were bailed from the well.

After two days of bailing, the turbidity remained at over 1000 NTU. Bailing was stopped and a 7.5-hp pump was inserted. Field parameters (pH, temperature, specific conductivity, and turbidity) were measured periodically during pumping. Each screened interval was developed by pumping four times: once until field parameters were acceptable or could not be improved (before moving to the next screen, the pump was shut off for 15 min); then again three times to make sure the acceptable or stable parameters could be reproduced. In Figure 7.3-1, the spikes in turbidity at 9890 gal. (18.5 NTU), 17,620 gal. (39.3 NTU), and 31,510 gal. (95.9 NTU) correspond to moving the pump from screen #4 to screen #5, screen #5 to screen #6, and screen #6 into the sump, respectively. A total of 39,770 gal. of water was pumped from the well. When all zones had been pumped satisfactorily, the well was considered to be developed. A summary of initial and final water-quality parameters during final well development is provided in Table 7.3-1.

Table 7.3-1

Summary of Final (Pumping) Phase of Development at CdV-R-15-3

				Range of Field Parameters[a]		
Screen[b]	**Elapsed Time (min)[c]**	**Water Produced (gal.)**	**pH**	**Temperature (°C)**	**Specific Conductance (µS/cm)**	**Turbidity[d]**
4	702	8860	5.1–7.7	17.8–18.3	105–99	28.2–1.40
5	477	7700	7.6–7.5	18.4–17.7	109–109	18.5–1.51
6	1297	16,160	7.8–7.6	18.8–18.5	281–105	39.3–2.21

[a] In each range, the first number is the value at the beginning and the second number is the value at end; intermediate values may be higher or lower.

[b] Screen #1 and screen #2 were dry and screen #3 was nearly dry, so they were not developed by pumping.

[c] Includes brief intervals when pump was off while being lowered to a new position relative to the screen.

[d] NTU = nephelometric turbidity units (goal is < 5 NTU). In each range, the first number is the turbidity at the start of development; the second number is the turbidity at the completion of development.

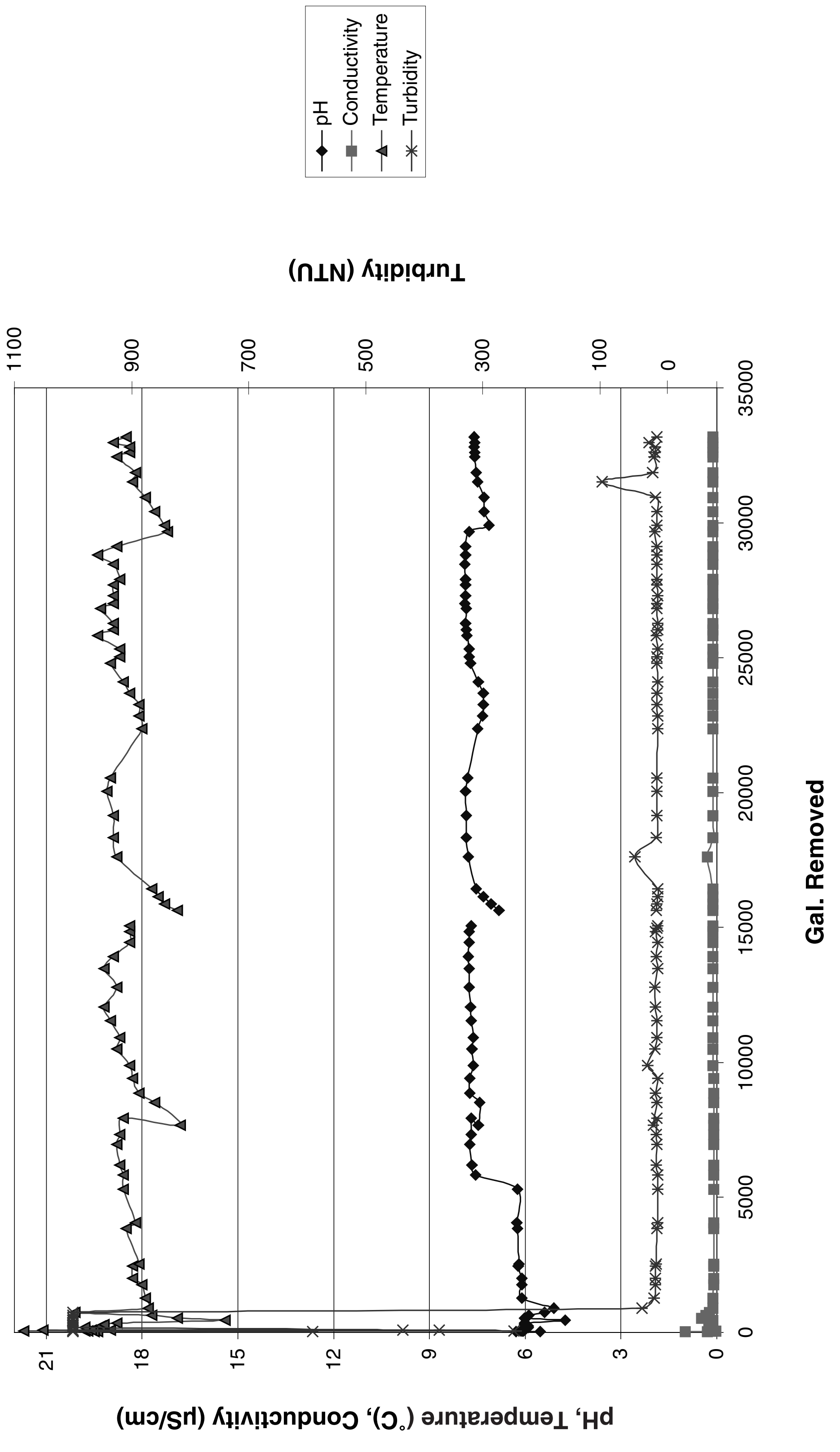


Figure 7.3-1.   Field parameters measured during well development

7.4 Installation of Westbay's MP55 System

Following well development, the Westbay (multi-port) MP55 System for groundwater monitoring was installed in the steel-cased well. Model 2523 MOSDAX System sampler probe equipment will be used to collect groundwater samples from the completed well.

An MP casing installation log, which specifies the location of each Westbay well component in the borehole, was prepared in the field by Westbay (in consultation with the Laboratory), based on a draft of the well-completion diagram. A natural gamma log taken inside the steel casing on August 11, 2000, was reviewed before measurement ports and packers were sited within the well-screen intervals. The final version of the MP casing installation log was approved on September 13, 2000, by the Laboratory, before installation of the Westbay well components took place. The MP casing installation log, as approved, was used as the installation guide in the field.

An MP measurement-port coupling and associated magnetic location collar were included in each primary monitoring zone to provide the capability for measuring fluid pressures and collecting fluid samples. One pumping-port coupling was also included in screens #1, #2, #3, #5, and #6; two pumping-port couplings were included in screen #4. Pumping ports are used for purging, sampling, and hydraulic conductivity testing. Additional measurement-port couplings were included below the pumping ports for monitoring hydraulic tests.

Measurement-port couplings were included in quality assurance (QA) zones to provide QA testing capabilities. All measurement ports were positioned below each of the MP55 packers to permit routine operation of the squeeze relief venting with the MP55 packer inflation equipment during the inflation process.

The MP casing components were set out in sequence, according to the MP casing installation log, on racks near the borehole. As an aid for confirming the proper sequence of components, each casing length was numbered in order, beginning with the lowermost. The appropriate MP System coupling was attached to each piece of MP casing. Magnetic location collars were attached 2.5 ft below measurement ports QA2, MPort1A, MPort 2A, MPort3A, MPort3B, MPort4A, MPort4B, MPort 5A, MPort6A, and 2.5 ft below MP coupling No. 198 near the top of the well.

The length of each MP casing section was measured with a steel tape to confirm nominal lengths, and the data were entered on the MP casing installation log. Each casing component was visually inspected and serial numbers for each packer, measurement-port coupling, and pumping-port coupling were recorded on the field copy of the MP casing installation log.

The MP casing components were lowered into the well in sequence. The first ten sections of MP casing were lowered by hand, and a Smeal work-over rig (provided by the Laboratory) was used to lower the remaining MP casing components. Each casing joint was tested with a minimum internal pressure of 300 psi for 1 min to confirm hydraulic seals. De-ionized water was used for the joint tests. A record of each successful joint test and the placement of each casing component appears on the field copy of the MP casing installation log. The suspended weight of the MP casing components was monitored during lowering to confirm that operating limits of the MP System casing were not exceeded.

After the casing was lowered into the borehole, the water level inside the MP casing was at a depth of more than 1369 ft below the top of the MP casing, confirming hydraulic integrity of the casing. The open-hole water level was about 1246 ft below ground level. The MP casing water level was too deep to measure with the available electric water level tape. A hydraulic integrity test was done by observing the water level inside the MP casing overnight during the pre-inflation pressure profile done on September 16 and 17, 2000. With this differential pressure acting on the MP casing string, the water level inside the MP casing was stable. The data from the hydraulic integrity test indicate that the MP casing was watertight.

After the components were lowered into the well and the hydraulic integrity of the MP casing had been confirmed, the MP casing string was positioned as shown in Appendix D. The MP packers were inflated on September 18 and 19, using de-ionized water. The packers were inflated in sequence beginning with the lowermost. All of the packers were inflated successfully and QA tests showed that all the packer valves were closed and sealed. Westbay's procedure for distressing the MP casing was used after all the packers had been inflated. The top MP55 casing (No. 199) was cut and trimmed to suit the final configuration of the wellhead assembly, and the MP top completion was installed. The final tensile load at the top of the MP casing was 450 lb. The maximum limit for long-term tensile loading of the MP casing is 1000 lb. A sketch of the as-built top of the MP casing and the final positions of the MP well components are shown in Appendix D. A summary of depth information for key MP well components is given in Table 7.4-1.

After packer inflation was completed, fluid pressures were measured at each measurement port. The fluid pressure profile measurements were taken on September 20, 2000. At that time, the in situ formation pressures may not have recovered from the pre-installation and installation activities. Longer term monitoring may be required to establish representative fluid pressures.

A plot of piezometric levels in all zones, including QA zones, based on the September 17 and September 20 pressure measurements, were examined to confirm proper operation of the measurement ports and as a check on the presence of annulus seals between adjacent monitoring zones. Each of the packers was supporting a differential hydraulic pressure, indicating the presence and effective operation of packer seals. All the measurement ports operated normally except for port 6B. Repeated tests were carried out at port 6B on September 20 and September 21, but the probe and measurement port valve could not be made to engage correctly. The behavior was consistent with a measurement-port valve not opening correctly. Port 6B is a "second" port in the zone, intended for use during hydraulic testing and as a backup to primary measurement-port 6A, which is used for sampling and pressure measurements. The malfunction of port 6B should not cause any loss of monitoring capability in the well.

7.5 Wellhead Protection

A concrete pad, 5 ft long by 10 ft wide by 6 in. thick, was placed around the wellhead. A 3-in. galvanized-steel pipe was placed toward the end of the pad (opposite the well casing) for future use as a solar panel attachment. The well is protected by a 14-in. steel protective casing with locking lid. Four 4-in. removable steel posts were placed at each corner just outside the pad boundaries. A brass survey marker was placed at the northwest corner of the pad.

Table 7.4-1
Depths of Key Items Installed During MP55 System Completion of CdV-R-15-3

Zone Number	Screen Interval (ft)[a]	Sand Pack Interval (ft)[a]	MP Casing Number (from MP Log)	Packer Number	Packer Serial Number (0612)	Nominal Packer Position (ft)[b]	Magnetic Collar Depth (ft)	Measurement Port Depth (ft)[b]	Pumping Port Depth (ft)[b]	Port Name	Comments
QA2			169				287.8	285.3		QA2	—
			168	1	102	295.6					—
QA1			138				None	584.9		QA1	—
			137	2	117	595.2					—
SQA1			136				None	599.7		SQA1	—
			135	3	158	605.1					—
Zone 1	617.7 to 624.5	598.2 to 629.0	132				626.8	624.3		MP1A	—
			131						629.7	PP1	—
			130					635.3		MP1B	
			129	4	106	638.9					—
LQA1			128					643.4		LQA1	—
			112	5	110	783.2					—
SQA2			111					787.7		SQA2	—
			110	6	112	793.0					—
Zone 2	800.8 to 807.8	779.7 to 805.8	108				809.8	807.3		MP2A	—
			107						812.6	PP2	—
			106					818.3		MP2B	—
			105	7	111	822.0					—
LQA2			104					826.5		LQA2	—
			92	8	107	944.9					—
SQA3			91					949.4		SQA3	—
			90	9	151	954.7					—

Table 7.4-1 (continued)
Depths of Key Items Installed During MP55 System Completion of CdV-R-15-3

Zone Number	Screen Interval (ft)[a]	Sand Pack Interval (ft)[a]	MP Casing Number (from MP Log)	Packer Number	Packer Serial Number (0612)	Nominal Packer Position (ft)[b]	Magnetic Collar Depth (ft)	Measurement Port Depth (ft)[b]	Pumping Port Depth (ft)[b]	Port Name	Comments
Zone 3	964.8 to 980.9	937.9 to 974.5	88				971.5	969.0		MP3A	—
			87				981.8	979.3		MP3B	—
			86						984.7	PP3A	—
			85					990.3		MP3C	—
			84	10	74	994.1					—
LQA3			83					998.5		LQA3	—
			61	11	56	1215.5					—
SQA4			60					1219.9		SQA4	—
			59	12	116	1225.3					—
Zone 4	1235.1 to 1278.9	1206.5 to 1286.5	55				1256.9	1254.4		MP4A	—
			54						1259.6	PP4A	—
			52				1277.6	1275.1		MP4B	—
			51						1280.5	PP4B	—
			50					1286.1		MP4C	—
			49	13	119	1289.8					—
LQA4			48					1294.3		LQA4	—
			43	14	109	1330.9					—
SQA5			42					1335.3		SQA5	—
			41	15	114	1340.7					—

Table 7.4-1 (continued)
Depths of Key Items Installed During MP55 System Completion of CdV-R-15-3

Zone Number	Screen Interval (ft)[a]	Sand Pack Interval (ft)[a]	MP Casing Number (from MP Log)	Packer Number	Packer Serial Number (0612)	Nominal Packer Position (ft)[b]	Magnetic Collar Depth (ft)	Measurement Port Depth (ft)[b]	Pumping Port Depth (ft)[b]	Port Name	Comments
Zone 5	1348.4 to 1355.3	1320.7 to 1348.5	39				1352.6	1350.1		MP5A	—
			38						1355.4	PP5	—
			37					1361.1		MP5B	—
			36	16	62	1364.8					—
LQA5			35					1369.3		LQA5	—
			9	17	153	1620.9					—
SQA6			8					1625.2		SAQ6	—
			7	18	103	1630.7					—
Zone 6	1637.9 to 1644.8	1604.0 to 1649.0	5				1642.6	1640.1		MP6A	—
			4						1645.5	PP6	—
			3					1651.1		MP6B	—
			2	19	115	1654.8					—
LQA6			1					1659.3		LQA6	—

[a] All depths measured with respect to ground level; depths of sand pack and screened intervals taken from LANL Well CdV-R15-3 fact sheet provided on February 5, 2001.

[b] Depth of MP casing component is depth to the top of the respective coupling.

8.0 SITE RESTORATION

A portion of the CdV-R-15-3 drill site area will be maintained as a level, graveled pad to serve as a work area for future groundwater sampling events and well maintenance. The site has been graded to prevent the puddling or ponding of surface water near the wellhead. Diversion channels with berms were cut above the wellhead to prevent surface water run-on from occurring. The cuttings pit and berms were regraded to prevent ponding, and the area surrounding the graveled pad was reseeded with native dryland seed; straw mulch was spread to promote revegetation.

9.0 MODIFICATIONS TO FIELD IMPLEMENTATION PLANS

Table 9.0-1 compares the activities planned in the “Addendum to CMS Plan for Potential Release Site 16-021(c)” (LANL 1999, 64873) and the “Field Implementation Plan [FIP] for the Drilling and Testing of LANL TA-16-260 Corrective Measures Study Well CdV-R-15-3” (ER Project 2000, 67305) with the activities performed at CdV-R-15-3.

The most significant modification from planned to actual activities was the open-hole drilling method that was employed. In the CMS addendum, a casing advance method was suggested. Because the borehole was relatively stable, it was advanced without drill casing. In addition, the CMS addendum specified that 5% of the borehole would be cored; however, the FIP specified that core would be collected as deemed necessary. Because no conditions were encountered for which the team determined it was necessary to core, no core was collected.

Other modifications to CdV-R-15-3 were relatively minor. For example, the length of the well sump was changed from the 10 ft specified in the CMS addendum to the 30 ft specified in the FIP and in the final installation.

Table 9.0-1
Activities Planned for CdV-R-15-3, Compared with Work Performed

	CMS Addendum	CdV-R-15-3 FIP	CdV-R-15-3 Actual Work
Planned Depth (ft)	1800 ft, or at least 200 ft into regional zone of saturation	At least 200 ft into regional zone of saturation: 1371–1950 ft	1722 ft (480 ft into regional zone of saturation)
Drilling Method	Casing advance to total depth of borehole	HSA to place surface casing, then casing advance with air-rotary equipment	HSA to place surface casing; open hole with polymer-assisted air-rotary equipment
Amount of Core	Five percent of borehole	As deemed necessary	No core collected
Lithologic Log	Log to be prepared from core, cuttings, and drilling performance	Log to be prepared from core, cuttings, and drilling performance	Log was prepared from core, cuttings, and drilling performance
Water Sample Field Measurements	HE spot test and D TECH immunoassay	pH, specific conductance, temperature, turbidity	D TECH, pH, specific conductance, temperature, turbidity
Number of Water Samples Collected for Contaminant Analysis	To provide a contaminant profile	Water sample to be collected from each saturated zone (and as directed by HEPS team leader or geochemistry principal investigator)	Five samples were collected for HE screening

Table 9.0-1 (continued)
Activities Planned for CdV-R-15-3, Compared with Work Performed

	CMS Addendum	CdV-R-15-3 FIP	CdV-R-15-3 Actual Work
Geophysics	Caliper, electromagnetic induction, natural gamma, magnetic susceptibility, color video, fluid temperature, fluid resistivity, single point resistivity, and spontaneous potential; for cased holes, gamma-gamma density, natural gamma, and thermal neutron	Gamma-gamma density, natural gamma, and thermal neutron	Natural gamma, color video, deviation survey, microimager, gamma ray, temperature, spinner, array induction, neutron porosity, natural gamma-ray spectrum, triple lithodensity, combinable magnetic resonance
Water-Level Measurements	Measurements to profile head gradients	When saturated conditions are encountered	When saturated conditions were suspected and drilling schedule permitted
Slug Tests	At key geologic intervals as determined by the technical team's hydrologist	As determined by the technical team's hydrologist	In the three screens located within the regional zone of saturation
Surface Casing	~16-in. diameter casing, from land surface to approximately 10 ft	16-in. surface casing, 10 ft into competent material	18-in. casing to 20 ft (18 ft into competent material)
Well Casing Size	5.56 in. OD	5.0 in. OD	5.0 in. OD
Well Screen	Number and length to be finalized in the field	Up to four 10-ft and one 20-ft 5.5-in. OD pipe-based screens	Three ~7-ft, one ~26-ft, and one ~ 44-ft 5.5-in. OD pipe-based screens
Filter Material	Not specified	> 90% silica sand; 20/40, 8/12, or other appropriate size	> 90% silica sand; 20/40, 8/12, and 6/9 in different locations
Conductor Casing	Carbon-steel casing from land surface to top of stainless-steel screen	ASTM standard A312 stainless steel	ASTM standard A312 stainless steel
Backfill materials (exclusive of filter materials)	Cement grout and bentonite	Bentonite and, where feasible, cement grout	Bentonite and, where feasible, cement grout
Sump	10 ft	30 ft	30 ft

10.0 IMPLICATIONS FOR CONCEPTUAL GEOLOGIC, HYDROGEOLOGIC, AND GEOCHEMICAL MODELS

10.1 The Geologic Model

Implications of the new information from CdV-R-15-3 for geologic models can be visualized in Figure 3.0-1, which provides a stratigraphic comparison with the Laboratory's 3-D geologic model that was current at the time of drilling. The major differences between the predicted and as-encountered geology are in the much thicker Cerro Toledo interval and the absence of axial river gravels (Tpt) or Santa Fe Group sediments (Tsfuv). These differences from the predicted stratigraphy are not unique to CdV-R-15-3, for the same deviations from the geologic model were found at R-19 and at R-25 (see Figure 3.0-3). The deviations from the 3-D geologic model at CdV-R-15-3 are thus not anomalous, but provide a broader context for similar results at R-19 and R-25. Future drill holes to the north and to the south of the section shown in Figure 3.0-

2 and Figure 3.0-3 will help define the morphology of the erosional low incised into the Otowi ash flows and filled by Cerro Toledo sediments.

In the stratigraphy beneath the Bandelier Tuff, CdV-R-15-3 provides the westernmost known occurrence of Cerros del Rio lavas. The unexpected occurrence of basaltic boulder debris at the bottom of the Cerros del Rio lavas suggests very active volcaniclastic processes along the western margin of the Cerros del Rio volcanic field. A local basaltic highland may be the source of this debris, but the implications of this deposit are difficult to determine from this one sampled occurrence.

The Puye Formation is much thicker and more varied beneath this portion of the Pajarito Plateau than was previously suspected. Correlation of fanglomerate subunits within the Puye is possible, but it is still uncertain whether this can be accomplished over lateral distances of more than a few kilometers beneath the Laboratory site. Studies of pumice compositions may provide the most useful markers of stratigraphic horizons within the Puye Formation. Moreover, the nature of pumice distributions, whether as relatively undisturbed pumice beds or as admixed clastic detritus, can be used to learn about the distribution of high-energy versus low-energy depositional environments in the Puye Formation. This information will be useful for defining the 3-D morphology of Puye subunits with differing hydrogeologic properties.

Comparing the Puye Formation deposits in CdV-R-15-3 with deposits of comparable depth in the R-19 borehole is informative. In CdV-R-15-3, the pumice beds below ~1518 ft are reworked and heterogeneous, unlike the relatively pure pumice horizons at depth in R-19. Moreover, the pumiceous material in CdV-R-15-3 appears to be chemically distinct (more rubidium-rich) from that in R-19. The general abundance of rhyolitic pumice below ~1518 ft in R-19 is also not evident in CdV-R-15-3, where intermediate-composition volcanic detritus of probable Tschicoma Formation origin predominates. Dispersal of pumice within fanglomerate materials at CdV-R-15-3 is an indication of higher-energy depositional environments in the deeper strata at CdV-R-15-3 than at comparable depths in R-19.

10.2 The Hydrogeologic Model

CdV-R-15-3 provides three hydrologic implications of for the conceptual hydrogeologic model:

1. The most significant is that the thick perched zone of saturation observed at R-25 was not encountered. In fact, the occurrence of any perched water at the well is uncertain.
2. The regional water table is 74 ft deeper than anticipated. However, this appears to be a consequence of contouring sparse water-level data in this region.
3. Hydrologic testing provided additional hydraulic conductivity values for the Puye Formation in this area, with hydraulic conductivities of 0.25–0.10 ft/d.

10.3 The Geochemical Model

The geochemical data from the six depth intervals collected for CdV-R-15-3 is generally consistent with the current geochemical conceptual model for the regional aquifer. Water quality is generally excellent in the borehole, and water chemistry is compatible with previous analyses of uncontaminated regional groundwater. The low TDS, and the associated low major cation and anion abundances, may indicate a lower degree of interaction with Puye Formation sediments than is typical for regional aquifer waters. Initial data suggest that HE concentrations are much less than those observed at R-25 and may be false positives due to drilling additives. These data indicate that the regional aquifer is probably not impacted by HE contamination. Planned quarterly sampling will provide more reliable evaluation of groundwater quality at this location.

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Appendix A

Drilling Chronology

CdV-R-15-3 Operations Chronology

12-hr Shift	Date	Day	Shift	From (time)	To (time)	Prod. From	Prod. To	Prod. (ft)	Time (hr:min)	Rate (ft/hr)	Activity
1.0	1/19/00	Wed.	D	8:10	11:00				2:50		Mobilized hollow-stem auger equipment to site.
1.0	1/19/00	Wed.	D	11:10	12:00	0.00	30.00	30.00	0:50	36.00	Advance 9-in. OD auger. Tuff encountered at 5 ft.
1.0	1/19/00	Wed.	D	13:12	14:09	0.00	20.00	20.00	0:57	21.05	Overream with 23-in. OD augers to 20 ft.
1.0	1/19/00	Wed.	D	14:09	14:40	30.00	0.00	30.00	0:31	58.06	Trip out 9-in. OD augers.
1.0	1/19/00	Wed.	D	15:00	16:15				1:15		Go to FSF for casing, etc.
1.0	1/19/00	Wed.	D	16:15	17:09	20.00	0.00	20.00	0:54	22.22	Trip out 23-in. augers.
1.0	1/19/00	Wed.	D	17:09	18:40				1:31		Piece of metal found in side of borehole, wait for ESH-1.
2.0	1/20/00	Thu.	D	7:00	8:30				1:30		Wait for ESH approval to start work after finding metal.
2.0	1/20/00	Thu.	D	8:30	9:45				1:15		Site access, safety tailgate.
2.0	1/20/00	Thu.	D	10:00	10:30				0:30		Ream the hole with center bit on 23-in. augers.
2.0	1/20/00	Thu.	D	10:30	13:00				2:30		Pump mud to stabilize hole. Let mud set hole.
2.0	1/20/00	Thu.	D	13:00	14:00	20.00	0.00	20.00	1:00	20.00	Trip out 23-in. augers.
2.0	1/20/00	Thu.	D	14:00	14:35	0.00	20.00	20.00	0:35	34.29	Trip in 16-in. surface casing.
2.0	1/20/00	Thu.	D	14:35	15:10				0:35		Cement casing in place.
3.0	2/16/00	Wed.	D	11:55	17:00				5:05		Drill pad preparation.
4.0	2/17/00	Thu.	D	8:00	17:05				9:05		Drill pad preparation.
5.0	2/18/00	Fri.	D	13:30	14:00				0:30		Excavate casing jack cellar. Construct drill pad.
5.0	2/18/00	Fri.	D	14:00	15:20				1:20		Metal and other debris found in excavation. Wait for an RCT.
5.0	2/18/00	Fri.	D	15:20	16:00				0:40		Continue excavation. More metal found. Culvert installed.
5.0	2/22/00	Tue.	D	9:40	9:45				0:05		Excavate steel tank from jack cellar pit. Construct drill pad.
5.0	2/22/00	Tue.	D	9:45	11:55				2:10		Hydraulic hose on backhoe repaired while waiting on asbestos determination on tank.
5.0	2/22/00	Tue.	D	11:55	15:10				3:15		Wait on asbestos determination. Construct drill pad.
6.0	2/23/00	Wed.	D	8:30	15:30				7:00		Construct drill pad.
7.0	2/24/00	Thu.	D	8:40	9:55				1:15		Construct drill pad.
8.0	2/25/00	Fri.	D	7:15	8:30				1:15		Asbestos awareness training.
8.0	2/25/00	Fri.	D	8:30	9:38				1:08		Get frozen equipment thawed and started.
8.0	2/25/00	Fri.	D	9:45	13:55				4:10		Work on jack cellar.

CdV-R-15-3 Operations Chronology (continued)

12-hr Shift	Date	Day	Shift	From (time)	To (time)	Prod. From	Prod. To	Prod. (ft)	Time (hr:min)	Rate (ft/hr)	Activity
9.0	2/28/00	Mon.	D	9:10	10:20				1:10		Work on jack cellar.
10.0	2/29/00	Tue.	D	7:00	9:00				2:00		Construct drill pad.
10.0	2/29/00	Tue.	D	12:20	16:30				4:10		Install perimeter fence.
11.0	3/1/00	Wed.	D	7:30	15:30				8:00		Spread base coarse and construct containment pits.
12.0	3/2/00	Thu.	D	9:00	16:30				7:30		Spread base coarse.
13.0	3/3/00	Fri.	D	9:00	14:00				5:00		Construct drill pad.
14.0	3/16/00	Thu.	D	7:00	13:45				6:45		Extend drill pad to the south to accommodate the rig.
15.0	3/16/00	Thu.	N	18:00	23:59				5:59		Mobilize DR rig and equipment.
16.0	3/17/00	Fri.	N	0:01	6:00				5:59		Mobilize DR rig and equipment.
17.0	3/17/00	Fri.	D	7:30	15:10				7:40		Site and rig setup.
17.0	3/17/00	Fri.	D	15:10	15:20	14.00	20.00	6.00	0:10	36.00	Drill out conductor casing.
17.0	3/17/00	Fri.	D	15:57	16:15	20.00	42.00	22.00	0:18	73.33	Advance 16-in. tricone open-hole.
17.0	3/17/00	Fri.	D	16:45	17:15				0:30		Site and rig setup.
18.0	3/17/00	Fri.	N	18:00	18:30				0:30		Site access, safety tailgate.
18.0	3/17/00	Fri.	N	18:30	23:59				5:29		Site and rig setup.
18.0	3/18/00	Sat.	N	0:00	0:30				0:30		Lunch
18.0	3/18/00	Sat.	N	0:30	1:20				0:50		Site and rig setup.
18.0	3/18/00	Sat.	N	1:20	6:15	22.00	147.00	125.00	4:55	25.42	Advance 16-in. tricone open-hole.
19.0	3/18/00	Sat.	D	6:15	13:00				6:45		Stuck in hole.
19.0	3/18/00	Sat.	D	13:00	15:00	147.00	157.00	10.00	2:00	5.00	Advance 16-in. tricone open-hole.
19.0	3/18/00	Sat.	D	15:00	16:30				1:30		Shut down for fuel and water.
19.0	3/18/00	Sat.	D	16:30	17:30				1:00		Refuel equipment.
20.0	3/18/00	Sat.	N	18:00	18:40				0:40		Site access, safety tailgate.
20.0	3/18/00	Sat.	N	19:15	21:00	157.00	162.00	5.00	1:45	2.86	Advance 16-in. tricone open-hole.
20.0	3/18/00	Sat.	N	21:30	23:00				1:30		Shut down for injury.
20.0	3/18/00	Sat.	N	23:00	0:30	162.00	0.00	162.00	1:30	108.00	Trip out 16-in. tricone.
20.0	3/19/00	Sun.	N	0:30	1:00				0:30		Lunch
20.0	3/19/00	Sun.	N	1:00	3:00				2:00		Unplug 16-in. tricone.
20.0	3/19/00	Sun.	N	3:00	4:50	0.00	162.00	162.00	1:50	88.36	Trip in 16-in. tricone.
20.0	3/19/00	Sun.	N	4:50	6:00	162.00	165.00	3.00	1:10	2.57	Advance 16-in. tricone open-hole.
21.0	3/19/00	Sun.	D	6:30	7:00				0:30		Site access, safety tailgate.

CdV-R-15-3 Operations Chronology (continued)

12-hr Shift	Date	Day	Shift	From (time)	To (time)	Prod. From	Prod. To	Prod. (ft)	Time (hr:min)	Rate (ft/hr)	Activity
21.0	3/19/00	Sun.	D	8:00	17:30	165.00	227.00	62.00	9:30	6.53	Advance 16-in. tricone open-hole.
22.0	3/19/00	Sun.	N	18:00	18:30				0:30		Site access, safety tailgate.
22.0	3/19/00	Sun.	N	18:30	22:45	227.00	287.00	60.00	4:15	14.12	Advance 16-in. tricone open-hole.
22.0	3/19/00	Sun.	N	22:45	0:45	287.00	322.00	35.00	2:00	17.50	Advance 16-in. tricone open-hole.
22.0	3/20/00	Mon.	N	0:45	1:45				1:00		Lunch
22.0	3/20/00	Mon.	N	1:45	2:20				0:35		Unplug 16-in. tricone.
22.0	3/20/00	Mon.	N	2:20	6:00	322.00	362.00	40.00	3:40	10.91	Advance 16-in. tricone open-hole.
23.0	3/20/00	Mon.	D	6:00	6:25				0:25		Site access, safety tailgate.
23.0	3/20/00	Mon.	D	6:25	13:45	362.00	472.00	110.00	7:20	15.00	Advance 16-in. tricone open-hole.
23.0	3/20/00	Mon.	D	13:45	14:30				0:45		Shutdown for repairs.
23.0	3/20/00	Mon.	D	14:30	15:38	472.00	482.00	10.00	1:08	8.82	Advance 16-in. tricone open-hole.
23.0	3/20/00	Mon.	D	15:38	17:30	482.00	502.00	20.00	1:52	10.71	Advance 16-in. tricone open-hole.
23.0	3/20/00	Mon.	D	17:30	18:00				0:30		Plugged.
23.0	3/20/00	Mon.	D	18:00	18:30				0:30		Site access, safety tailgate.
23.0	3/20/00	Mon.	D	18:30	18:50				0:20		Plugged.
23.0	3/20/00	Mon.	D	18:50	23:25	502.00	0.00	502.00	4:35	109.53	Trip out 16-in. tricone.
24.0	3/21/00	Tue.	N	0:00	1:00				1:00		Lunch.
24.0	3/21/00	Tue.	N	1:00	6:00				5:00		Unplug 16-in. tricone.
25.0	3/21/00	Tue.	D	6:00	6:25				0:25		Site access, safety tailgate.
25.0	3/21/00	Tue.	D	6:25	9:00				2:35		Unplug 16-in. tricone.
25.0	3/21/00	Tue.	D	9:00	11:35	0.00	422.00	422.00	2:35	163.35	Trip in 16-in. tricone.
25.0	3/21/00	Tue.	D	11:35	13:10				1:35		Repair dust head.
25.0	3/21/00	Tue.	D	13:10	13:40	422.00	482.00	60.00	0:30	120.00	Trip in 16-in. tricone.
25.0	3/21/00	Tue.	D	13:40	14:40	482.00	502.00	20.00	1:00	20.00	Clean hole.
25.0	3/21/00	Tue.	D	14:40	18:00				3:20		Repair dust head.
26.0	3/21/00	Tue.	N	18:00	18:30				0:30		Site access, safety tailgate.
26.0	3/21/00	Tue.	N	18:30	21:00				2:30		Fill water trucks.
26.0	3/21/00	Tue.	N	21:00	23:59				2:59		Repair dust head.
26.0	3/22/00	Wed.	N	0:00	1:40	482.00	502.00	20.00	1:40	12.00	Clean hole.
26.0	3/22/00	Wed.	N	1:40	2:40				1:00		Plugged.
26.0	3/22/00	Wed.	N	2:40	5:10	502.00	522.00	20.00	2:30	8.00	Advance 16-in. tricone open-hole.

CdV-R-15-3 Operations Chronology (continued)

12-hr Shift	Date	Day	Shift	From (time)	To (time)	Prod. From	Prod. To	Prod. (ft)	Time (hr:min)	Rate (ft/hr)	Activity
26.0	3/22/00	Wed.	N	5:10	6:00				0:50		Service rig.
27.0	3/22/00	Wed.	D	6:00	6:30				0:30		Site access, safety tailgate.
27.0	3/22/00	Wed.	D	6:30	13:55	522.00	612.00	90.00	7:25	12.13	Advance 16-in. tricone open-hole.
27.0	3/22/00	Wed.	D	13:55	14:10				0:15		Air lift.
27.0	3/22/00	Wed.	D	14:10	14:40	612.00	622.00	10.00	0:30	20.00	Advance 16-in. tricone open-hole.
27.0	3/22/00	Wed.	D	14:40	18:30				3:50		Water level measurements.
28.0	3/22/00	Wed.	N	18:30	19:00				0:30		Site access, safety tailgate.
28.0	3/22/00	Wed.	N	19:00	22:15				3:15		Water level measurements.
28.0	3/22/00	Wed.	N	22:15	1:40				3:25		Water sample.
28.0	3/23/00	Thu.	N	1:40	5:40	622.00	677.00	55.00	4:00	13.75	Advance 16-in. tricone open-hole.
29.0	3/23/00	Thu.	D	6:00	7:15				1:15		Fuel rig.
29.0	3/23/00	Thu.	D	7:15	11:28	677.00	722.00	45.00	4:13	10.67	Advance 16-in. tricone open-hole.
29.0	3/23/00	Thu.	D	11:28	12:30				1:02		Standby. Meet w/ client.
29.0	3/23/00	Thu.	D	12:30	12:50	722.00	622.00	100.00	0:20	300.00	Trip out 16-in. tricone.
29.0	3/23/00	Thu.	D	12:50	18:00				5:10		Shut down for rig repairs.
30.0	3/23/00	Thu.	N	18:00	18:30				0:30		Site access, safety tailgate.
30.0	3/23/00	Thu.	N	18:30	22:00	622.00	0.00	622.00	3:30	177.71	Trip out 16-in. tricone.
30.0	3/23/00	Thu.	N	22:40	0:15	0.00	600.00	600.00	1:35	378.95	Trip in 7-in. rods.
30.0	3/24/00	Fri.	N	0:15	1:40				1:25		Cement hole.
30.0	3/24/00	Fri.	N	1:40	2:10				0:30		Secure site.
31.0	3/25/00	Sat.	D	5:30	7:20				1:50		Site access, safety tailgate.
31.0	3/25/00	Sat.	D	7:20	8:01				0:41		Sound hole.
31.0	3/25/00	Sat.	D	8:10	11:15	600.00	0.00	600.00	3:05	194.59	Trip out 7-in. rods (w/ training).
31.0	3/25/00	Sat.	D	11:15	19:00				7:45		Log hole (LANL truck).
32.0	3/25/00	Sat.	N	18:00	22:30				4:30		Mobilize 13 5/8-in. casing.
32.0	3/25/00	Sat.	N	22:30	6:00				7:30		Site and rig setup (prep to run 13 5/8-in. casing).
33.0	3/26/00	Sun.	D	6:00	12:00				6:00		Reposition rig and set up casing jacks.
33.0	3/26/00	Sun.	D	12:30	18:00	0.00	230.00	230.00	5:30	41.82	Trip 13 5/8-in. casing from 0 to 220 ft.
34.0	3/26/00	Sun.	N	18:00	18:40				0:40		Load 13 5/8-in. casing.
34.0	3/26/00	Sun.	N	18:40	19:00				0:20		Site access, safety tailgate.
34.0	3/26/00	Sun.	N	19:30	20:35				1:05		Unload 13 5/8-in. casing.

CdV-R-15-3 Operations Chronology (continued)

12-hr Shift	Date	Day	Shift	From (time)	To (time)	Prod. From	Prod. To	Prod. (ft)	Time (hr:min)	Rate (ft/hr)	Activity
34.0	3/26/00	Sun.	N	20:35	23:20	230.00	450.00	220.00	2:45	80.00	Trip in 13 5/8-in. casing.
34.0	3/26/00	Sun.	N	23:40	1:07				1:27		Mobilize 13 5/8-in. casing.
34.0	3/27/00	Mon	N	1:07	3:50	450.00	670.00	220.00	2:43	80.98	Trip in 13 5/8-in. casing.
34.0	3/27/00	Mon	N	3:50	5:50				2:00		Mobilize 13 5/8-in. casing.
35.0	3/27/00	Mon	D	6:30	6:45				0:15		Site access, safety tailgate.
35.0	3/27/00	Mon	D	7:00	7:40	670.00	705.00	35.00	0:40	52.50	Trip in 13 5/8-in. casing.
35.0	3/27/00	Mon	D	7:40	8:30				0:50		Mobilize 13 5/8-in. casing.
35.0	3/27/00	Mon	D	8:30	9:55	705.00	722.00	17.00	1:25	12.00	Trip in 13 5/8-in. casing.
35.0	3/27/00	Mon	D	9:55	12:00				2:05		Site and rig setup (prep to run 12 1/4-in. tricone bit open-hole).
35.0	3/27/00	Mon	D	12:00	14:15	0.00	660.00	660.00	2:15	293.33	Trip in 12 1/4-in. tricone bit.
35.0	3/27/00	Mon	D	15:00	17:00				2:00		Clean out cuttings pond.
36.0	3/27/00	Mon	N	18:00	19:55				1:55		Site setup. Line cuttings pond with plastic.
36.0	3/27/00	Mon	N	19:55	20:30				0:35		Fill water trucks.
36.0	3/27/00	Mon	N	20:30	21:45	660.00	722.00	62.00	1:15	49.60	Trip in 12 1/4-in. tricone bit.
36.0	3/27/00	Mon	N	21:45	0:00	722.00	727.00	5.00	2:15	2.22	Advance 12 1/4-in. tricone bit.
36.0	3/28/00	Tue.	N	0:00	4:00				4:00		Repair dust head.
36.0	3/28/00	Tue.	N	4:00	6:00	727.00	747.00	20.00	2:00	10.00	Advance 12 1/4-in. tricone bit.
37.0	3/28/00	Tue.	D	6:00	6:20				0:20		Site access, safety tailgate.
37.0	3/28/00	Tue.	D	6:20	11:15	747.00	824.00	77.00	4:55	15.66	Advance 12 1/4-in. tricone bit.
37.0	3/28/00	Tue.	D	11:15	13:10				1:55		Fill water trucks.
37.0	3/28/00	Tue.	D	13:10	18:00	824.00	856.00	32.00	4:50	6.62	Advance 12 1/4-in. tricone bit.
38.0	3/28/00	Tue.	N	18:00	19:00				1:00		Fill water trucks.
38.0	3/28/00	Tue.	N	19:00	19:30				0:30		Site access, safety tailgate.
38.0	3/28/00	Tue.	N	19:30	0:57	856.00	872.00	16.00	5:27	2.94	Advance 12 1/4-in. tricone bit.
38.0	3/29/00	Wed.	N	1:38	2:50				1:12		Repair compressor.
38.0	3/29/00	Wed.	N	2:50	6:02	872.00	892.00	20.00	3:12	6.25	Advance 12 1/4-in. tricone bit.
39.0	3/29/00	Wed.	D	6:02	7:19	892.00	902.00	10.00	1:17	7.79	Advance 12 1/4-in. tricone bit.
39.0	3/29/00	Wed.	D	7:38	8:07				0:29		Air lift.
39.0	3/29/00	Wed.	D	8:07	10:00				1:53		Recharge.
39.0	3/29/00	Wed.	D	10:00	14:30	902.00	922.00	20.00	4:30	4.44	Advance 12 1/4-in. tricone bit.

CdV-R-15-3 Operations Chronology (continued)

12-hr Shift	Date	Day	Shift	From (time)	To (time)	Prod. From	Prod. To	Prod. (ft)	Time (hr:min)	Rate (ft/hr)	Activity
39.0	3/29/00	Wed.	D	14:30	15:30				1:00		Refuel rig.
39.0	3/29/00	Wed.	D	15:40	18:45	922.00	942.00	20.00	3:05	6.49	Advance 12 1/4-in. tricone bit.
40.0	3/29/00	Wed.	N	18:45	19:00				0:15		Site access, safety tailgate.
40.0	3/29/00	Wed.	N	19:00	21:40	942.00	962.00	20.00	2:40	7.50	Advance 12 1/4-in. tricone bit.
40.0	3/29/00	Wed.	N	21:52	23:20				1:28		Fill water trucks.
40.0	3/30/00	Thu	N	0:20	0:45				0:25		Refuel rig.
40.0	3/30/00	Thu	N	1:10	5:30	962.00	1002.00	40.00	4:20	9.23	Advance 12 1/4-in. tricone bit.
40.0	3/30/00	Thu	N	5:30	6:00				0:30		Refuel rig.
41.0	3/30/00	Thu	D	6:00	6:30				0:30		Site access, safety tailgate.
41.0	3/30/00	Thu	D	6:30	7:15				0:45		Fill water trucks.
41.0	3/30/00	Thu	D	7:50	10:56	1002.00	1012.00	10.00	3:06	3.23	Advance 12 1/4-in. tricone bit.
41.0	3/30/00	Thu	D	10:56	11:20				0:24		Air lift.
41.0	3/30/00	Thu	D	11:20	11:31				0:11		Recharge.
41.0	3/30/00	Thu	D	11:40	12:44	1012.00	1022.00	10.00	1:04	9.38	Advance 12 1/4-in. tricone bit.
41.0	3/30/00	Thu	D	13:03	13:10				0:07		Air lift.
41.0	3/30/00	Thu	D	13:10	13:17				0:07		Recharge.
41.0	3/30/00	Thu	D	13:17	13:30				0:13		Air lift.
41.0	3/30/00	Thu	D	13:30	14:57	1022.00	1027.00	5.00	1:27	3.45	Advance 12 1/4-in. tricone bit.
41.0	3/30/00	Thu	D	14:57	16:15				1:18		Recharge.
41.0	3/30/00	Thu	D	16:15	16:25				0:10		Water level measurements.
41.0	3/30/00	Thu	D	16:25	17:52	1027.00	1032.00	5.00	1:27	3.45	Advance 12 1/4-in. tricone bit.
42.0	3/30/00	Thu	N	18:00	18:30				0:30		Site access, safety tailgate.
42.0	3/30/00	Thu	N	18:30	23:58	1032.00	1062.00	30.00	5:28	5.49	Advance 12 1/4-in. tricone bit.
42.0	3/31/00	Fri	N	0:00	1:10	1062.00	1065.00	3.00	1:10	2.57	Advance 12 1/4-in. tricone bit.
42.0	3/31/00	Fri	N	1:10	2:20				1:10		Fill water trucks.
42.0	3/31/00	Fri	N	2:20	5:30	1065.00	1087.00	22.00	3:10	6.95	Advance 12 1/4-in. tricone bit.
43.0	3/31/00	Fri	D	6:00	6:30				0:30		Site access, safety tailgate.
43.0	3/31/00	Fri	D	5:30	14:45	1087.00	1137.00	50.00	9:15	5.41	Advance 12 1/4-in. tricone bit.
43.0	3/31/00	Fri	D	14:45	15:30				0:45		Air lift.
43.0	3/31/00	Fri	D	15:30	16:30				1:00		Recharge.
43.0	3/31/00	Fri	D	16:30	16:53				0:23		Water sample.

CdV-R-15-3 Operations Chronology (continued)

12-hr Shift	Date	Day	Shift	From (time)	To (time)	Prod. From	Prod. To	Prod. (ft)	Time (hr:min)	Rate (ft/hr)	Activity
43.0	3/31/00	Fri	D	17:11	17:31	1137.00	1140.00	3.00	0:20	9.00	Advance 12 1/4-in. tricone bit.
44.0	3/31/00	Fri	N	18:00	18:30				0:30		Site access, safety tailgate.
44.0	3/31/00	Fri	N	18:30	1:30	1140.00	0.00	1140.00	7:00	162.86	Trip out 12 1/4-in. tricone bit.
44.0	4/1/00	Sat	N	1:30	2:00				0:30		Secure site.
45.0	4/1/00	Sat	D	9:00	14:00				5:00		Standby. Replace 12 1/4-in. bit.
45.0	4/1/00	Sat	D	14:10	18:05	0.00	1120.00	1120.00	3:55	285.96	Trip in 12 1/4-in. tricone bit.
46.0	4/1/00	Sat	N	18:05	21:00				2:55		Site and rig setup (prep to run 12 1/4-in. tricone bit open-hole).
46.0	4/1/00	Sat	N	21:00	23:15	1120.00	1122.00	2.00	2:15	0.89	Advance 12 1/4-in. tricone bit (clean hole).
46.0	4/2/00	Sun	N	0:00	0:30	1122.00	1127.00	5.00	0:30	10.00	Advance 12 1/4-in. tricone bit.
46.0	4/2/00	Sun	N	0:45	4:00				3:15		Refuel rig. Secure site. Standby for repairs (broken fan belt).
47.0	4/2/00	Sun	D	14:00	15:00				1:00		Repair fan belt.
47.0	4/2/00	Sun	D	15:00	16:00	1127.00	1132.00	5.00	1:00	5.00	Advance 12 1/4-in. tricone bit.
47.0	4/2/00	Sun	D	16:00	16:20				0:20		Fill water trucks.
47.0	4/2/00	Sun	D	16:20	17:55	1132.00	1152.00	20.00	1:35	12.63	Advance 12 1/4-in. tricone bit.
48.0	4/2/00	Sun	N	18:00	18:30				0:30		Site access, safety tailgate.
48.0	4/2/00	Sun	N	18:30	18:50	1152.00	1162.00	10.00	0:20	30.00	Advance 12 1/4-in. tricone bit.
48.0	4/2/00	Sun	N	18:50	23:00				4:10		Plugged.
48.0	4/2/00	Sun	N	23:00	0:00	1162.00	1182.00	20.00	1:00	20.00	Advance 12 1/4-in. tricone bit.
48.0	4/3/00	Mon	N	0:00	2:25	1182.00	1202.00	20.00	2:25	8.28	Advance 12 1/4-in. tricone bit.
48.0	4/3/00	Mon	N	2:30	3:05				0:35		Fill water trucks.
48.0	4/3/00	Mon	N	3:05	6:05	1202.00	1227.00	25.00	3:00	8.33	Advance 12 1/4-in. tricone bit.
49.0	4/3/00	Mon	D	6:05	6:50				0:45		Refuel rig.
49.0	4/3/00	Mon	D	6:50	7:00				0:10		Clean hole.
49.0	4/3/00	Mon	D	7:00	9:45	1227.00	1262.00	35.00	2:45	12.73	Advance 12 1/4-in. tricone bit.
49.0	4/3/00	Mon	D	10:40	11:35				0:55		Clean hole.
49.0	4/3/00	Mon	D	11:50	12:27				0:37		Water level measurements.
49.0	4/3/00	Mon	D	12:27	17:55	1262.00	1322.00	60.00	5:28	10.98	Advance 12 1/4-in. tricone bit.
50.0	4/3/00	Mon	N	18:00	18:30				0:30		Site access, safety tailgate.
50.0	4/3/00	Mon	N	18:00	0:15	1322.00	1402.00	80.00	6:15	12.80	Advance 12 1/4-in. tricone bit.

CdV-R-15-3 Operations Chronology (continued)

12-hr Shift	Date	Day	Shift	From (time)	To (time)	Prod. From	Prod. To	Prod. (ft)	Time (hr:min)	Rate (ft/hr)	Activity
50.0	4/4/00	Tue	N	0:15	1:50				1:35		Fill water trucks.
50.0	4/4/00	Tue	N	1:50	3:42	1402.00	1422.00	20.00	1:52	10.71	Advance 12 1/4-in. tricone bit.
50.0	4/4/00	Tue	N	3:45	4:05				0:20		Clean hole.
50.0	4/4/00	Tue	N	4:05	6:00	1422.00	1444.00	22.00	1:55	11.48	Advance 12 1/4-in. tricone bit.
51.0	4/4/00	Tue	D	7:00	7:30				0:30		Site access, safety tailgate.
51.0	4/4/00	Tue	D	7:30	12:25				4:55		Repair discharge hose.
51.0	4/4/00	Tue	D	12:25	18:00				5:35		Log hole (LANL truck).
52.0	4/4/00	Tue	N	18:00	18:30				0:30		Site access, safety tailgate.
52.0	4/4/00	Tue	N	19:50							Measure DTW at 955.9 ft bgs.
52.0	4/4/00	Tue	N	20:05	23:00				2:55		Collect water sample from 1442-ft depth.
52.0	4/4/00	Tue	N	23:00	23:59	1442.00	1452.00	10.00	0:59	10.17	Advance open hole with 12.25-in. tricone bit.
52.0	4/5/00	Wed.	N	0:01	2:30	1452.00	1482.00	30.00	2:29	12.08	Advance open hole with 12.25-in. tricone bit.
52.0	4/5/00	Wed.	N	2:30	3:50				1:20		Refuel equipment and get more water.
52.0	4/5/00	Wed.	N	3:50	4:20				0:30		Collect water sample from 1482-ft depth.
52.0	4/5/00	Wed.	N	4:20	6:00	1482.00	1497.00	15.00	1:40	9.00	Advance open hole with 12.25-in. tricone bit.
53.0	4/5/00	Wed.	D	6:00	6:15				0:15		Collect water sample from 1497 ft.
53.0	4/5/00	Wed.	D	6:15	8:15	1497.00	1522.00	25.00	2:00	12.50	Advance open hole with 12.25-in. tricone bit.
53.0	4/5/00	Wed.	D	8:15	18:00				9:45		Work to free stuck drill bit at 1522 ft.
54.0	4/5/00	Wed.	N	18:00	23:59				5:59		Work to free stuck drill bit at 1522 ft.
54.0	4/6/00	Thu	N	0:01	6:00				5:59		Work to free stuck drill bit at 1522 ft.
55.0	4/6/00	Thu	D	6:00	18:00				12:00		Work to free stuck drill bit at 1522 ft.
56.0	4/6/00	Thu	N	18:00	23:59				5:59		Work to free stuck drill bit at 1522 ft.
56.0	4/7/00	Fri	N	0:01	6:00				5:59		Work to free stuck drill bit at 1522 ft.
57.0	4/7/00	Fri	D	6:00	14:00				8:00		Work to free stuck drill bit at 1522 ft.
57.0	4/7/00	Fri	D	13:00	14:00				1:00		Collect water characterization samples from storage.
57.0	4/7/00	Fri	D	14:00	18:00				4:00		Repair hydraulic oil leak behind control panel.
58.0	4/7/00	Fri	N	18:00	23:59				5:59		Repair hydraulic oil leak behind control panel.
58.0	4/8/00	Sat	N	0:01	3:30				3:29		Repair hydraulic oil leak behind control panel.
58.0	4/8/00	Sat	N	3:30	6:00				2:30		Drill rig maintenance.
59.0	4/8/00	Sat	D	6:00	10:45				4:45		Work to free stuck drill bit at 1522 ft.
59.0	4/8/00	Sat	D	10:45	14:00				3:15		Bring A rods out to wash down to bit.

CdV-R-15-3 Operations Chronology (continued)

12-hr Shift	Date	Day	Shift	From (time)	To (time)	Prod. From	Prod. To	Prod. (ft)	Time (hr:min)	Rate (ft/hr)	Activity
59.0	4/8/00	Sat	D	14:00	16:00	0.00	760.00	760.00	2:00	380.00	Trip in A rods.
59.0	4/8/00	Sat	D	16:00	18:00				2:00		Rig repairs.
60.0	4/8/00	Sat	N	18:00	23:59				5:59		Drill rig repairs.
60.0	4/9/00	Sun	N	0:01	6:00				5:59		Drill rig repairs.
61.0	4/9/00	Sun	D	6:00	18:00				12:00		Drill rig repairs.
62.0	4/9/00	Sun	N	18:00	23:59				5:59		Drill rig repairs.
62.0	4/10/00	Mon	N	0:01	6:00				5:59		Drill rig repairs.
63.0	4/10/00	Mon	D	6:00	18:00				12:00		Drill rig repairs.
64.0	4/10/00	Mon	N	18:00	23:59				5:59		Drill rig repairs.
64.0	4/11/00	Tue	N	0:01	6:00				5:59		Drill rig repairs.
65.0	4/11/00	Tue	D	6:00	18:00				12:00		Drill rig repairs.
66.0	4/11/00	Tue	N	18:00	23:59				5:59		Drill rig repairs.
66.0	4/12/00	Wed.	N	0:01	6:00				5:59		Drill rig repairs.
67.0	4/12/00	Wed.	D	6:00	18:00				12:00		Drill rig repairs.
67.0	4/12/00	Wed.	D	12:00	13:00				1:00		Deploy transducer. DTW = 819.5 ft bgs. Rods are plugged.
68.0	4/12/00	Wed.	N	18:00	23:59				5:59		Drill rig repairs.
68.0	4/13/00	Thu	N	0:01	6:00				5:59		Drill rig repairs.
69.0	4/13/00	Thu	D	6:00	18:00				12:00		Drill rig repairs.
70.0	4/13/00	Thu	N	18:00	23:59				5:59		Drill rig repairs.
70.0	4/14/00	Fri	N	0:01	6:00				5:59		Drill rig repairs.
71.0	4/14/00	Fri	D	6:00	18:00				12:00		Drill rig repairs.
72.0	4/14/00	Fri	N	18:00	21:00				3:00		Drill rig repairs.
72.0	4/14/00	Fri	N	21:00	22:40	760.00	1360.00	600.00	1:40	360.00	Trip in A rods.
72.0	4/14/00	Fri	N	22:40	23:59	1360.00	1460.00	100.00	1:19	75.95	Wash down with A rods injecting TORKease solution.
72.0	4/15/00	Sat	N	0:01	2:20	1460.00	1505.00	45.00	2:19	19.42	Wash down with A rods injecting TORKease solution.
72.0	4/15/00	Sat	N	2:20	5:35	1505.00	0.00	1505.00	3:15	463.08	Trip out A rods.
73.0	4/15/00	Sat	D	7:15	9:30	0.00	1420.00	1420.00	2:15	631.11	Trip A rods inside drill rods to top of fill.
73.0	4/15/00	Sat	D	9:30	15:00	1320.00	1520.00	200.00	5:30	36.36	Pull back to 1320 ft, clear rods, and wash down to drill bit.
73.0	4/15/00	Sat	D	15:00	18:00	1520.00	0.00	1520.00	3:00	506.67	Trip out A rods.

CdV-R-15-3 Operations Chronology (continued)

12-hr Shift	Date	Day	Shift	From (time)	To (time)	Prod. From	Prod. To	Prod. (ft)	Time (hr:min)	Rate (ft/hr)	Activity
74.0	4/15/00	Sat	N	18:00	21:00				3:00		Rig up to attempt to regain rotation.
74.0	4/15/00	Sat	N	21:00	23:59				2:59		Work to free stuck drill bit at 1522 ft.
74.0	4/16/00	Sun	N	0:01	1:00				0:59		Drill bit unstuck.
74.0	4/16/00	Sun	N	1:00	6:00	1522.00	1422.00	100.00	5:00	20.00	Trip out 7-in. drill rods.
75.0	4/16/00	Sun	D	6:00	18:00	1422.00	700.00	722.00	12:00	60.17	Trip out 7-in. drill rods.
76.0	4/16/00	Sun	N	18:00	23:59	700.00	300.00	400.00	5:59	66.85	Trip out 7-in. drill rods.
76.0	4/17/00	Mon	N	0:01	2:02	300.00	0.00	300.00	2:01	148.76	Trip out 7-in. drill rods.
76.0	4/17/00	Mon	N	2:02	6:00				3:58		Rig down to swap drill rigs.
77.0	4/17/00	Mon	D	6:00	18:00				12:00		Prepare to swap drill rigs.
77.0	4/17/00	Mon	D	18:00							Use transducer to measure DTW at 1155.35 ft bgs.
78.0	4/17/00	Mon	N	18:00	23:59				5:59		Swap drill rigs.
78.0	4/18/00	Tue	N	0:01	5:15	0.00	1200.00	1200.00	5:14	229.30	Trip in 7-in. drill rods.
78.0	4/18/00	Tue	N	5:15	6:00				0:45		Re-center drill rig.
79.0	4/18/00	Tue	D	6:00	7:50				1:50		Re-center drill rig.
79.0	4/18/00	Tue	D	7:50	8:30	1200.00	1460.00	260.00	0:40	390.00	Trip in 7-in. drill rods.
79.0	4/18/00	Tue	D	8:30	11:35				3:05		Rig up to circulate in to TD.
79.0	4/18/00	Tue	D	11:45	13:37				1:52		Repair hydraulic oil leak from top head.
79.0	4/18/00	Tue	D	13:37	18:00				4:23		Circulate down toward TD = 1522 ft.
79.0	4/18/00	Tue	N	18:00	20:30				2:30		Work to unplug bit.
79.0	4/18/00	Tue	N	20:30	22:00	1480.00	1180.00	300.00	1:30	200.00	Trip out 7-in. drill rods.
79.0	4/18/00	Tue	N	23:00	23:59	1180.00	900.00	280.00	0:59	284.75	Trip out 7-in. drill rods.
79.0	4/19/00	Wed.	N	0:40	5:30	900.00	0.00	900.00	4:50	186.21	Trip out remaining rods. Last 120 ft plugged.
80.0	4/19/00	Wed.	D	6:00	7:45				1:45		Inspect RC rods for holes in center tube.
80.0	4/19/00	Wed.	D	7:45	12:00	0.00	1200.00	1200.00	4:15	282.35	Trip in 7-in. drill rods.
80.0	4/19/00	Wed.	D	13:05	13:35	1200.00	1400.00	200.00	0:30	400.00	Trip in 7-in. drill rods.
80.0	4/19/00	Wed.	D	13:35	15:30				1:55		Rig up to circulate in to TD.
80.0	4/19/00	Wed.	D	15:45	18:00				2:15		Stop to repair loose dusthead.
81.0	4/19/00	Wed.	N	18:00	20:30				2:30		Stop to repair loose dusthead.
81.0	4/19/00	Wed.	N	20:30	23:50				3:20		Circulate down to TD = 1522 ft.
81.0	4/20/00	Thu	N	0:01	2:50				2:49		Work on circulation pump.
81.0	4/20/00	Thu	N	2:50	3:20				0:30		Clean hole.

CdV-R-15-3 Operations Chronology (continued)

12-hr Shift	Date	Day	Shift	From (time)	To (time)	Prod. From	Prod. To	Prod. (ft)	Time (hr:min)	Rate (ft/hr)	Activity
81.0	4/20/00	Thu	N	3:20	6:00				2:40		Off-site for replacement hydraulic hose.
82.0	4/20/00	Thu	D	6:00	10:30				4:30		Complete hydraulic repairs.
82.0	4/20/00	Thu	D	10:30	11:50				1:20		Clean hole.
82.0	4/20/00	Thu	D	11:50	13:15	1522.00	1557.00	35.00	1:25	24.71	Advance open-hole with 12.25-in. tricone bit.
82.0	4/20/00	Thu	D	13:15	15:30				2:15		Work on pack-off between 13-in. and 18-in. casings.
82.0	4/20/00	Thu	D	15:45	16:05	1557.00	1562.00	5.00	0:20	15.00	Advance open-hole with 12.25-in. tricone bit.
82.0	4/20/00	Thu	D	16:05	18:00				1:55		Work to unplug rods.
83.0	4/20/00	Thu	N	19:00	21:00				2:00		Establish circulation, clean hole.
83.0	4/20/00	Thu	N	21:00	23:30	1562.00	1602.00	40.00	2:30	16.00	Advance open-hole with 12.25-in. tricone bit.
83.0	4/21/00	Fri	N	0:01	3:00				2:59		Off-site to get more drill rods.
83.0	4/21/00	Fri	N	3:00	4:10				1:10		Establish circulation, clean hole.
83.0	4/21/00	Fri	N	4:30	5:30	1602.00	1612.00	10.00	1:00	10.00	Advance open-hole with 12.25-in. tricone bit.
83.0	4/21/00	Fri	N	5:30	6:30	1612.00	1500.00	112.00	1:00	112.00	Trip out 7-in. drill rods.
84.0	4/24/00	Mon	D	7:30	10:25	1440.00	1612.00	172.00	2:55	58.97	Circulate down to TD = 1612 ft.
84.0	4/24/00	Mon	D	10:25	14:45	1612.00	1627.00	15.00	4:20	3.46	Advance open-hole with 12.25-in. tricone bit.
84.0	4/24/00	Mon	D	14:45	18:00				3:15		Bit plugged and stuck.
85.0	4/24/00	Mon	N	18:00	20:33				2:33		Bit plugged and stuck.
85.0	4/24/00	Mon	N	20:33	23:59	1627.00	1642.00	15.00	3:26	4.37	Clean hole.
85.0	4/25/00	Tue	N	1:10	4:50	1642.00	1682.00	40.00	3:40	10.91	Advance open-hole with 12.25-in. tricone bit.
85.0	4/25/00	Tue	N	4:50	5:20				0:30		Clean hole.
86.0	4/25/00	Tue	D	6:30	8:30	1682.00	1686.00	4.00	2:00	2.00	Advance open-hole with 12.25-in. tricone bit.
86.0	4/25/00	Tue	D	8:30	10:25				1:55		Work to unplug bit.
86.0	4/25/00	Tue	D	11:02	18:00	1686.00	1722.00	36.00	6:58	5.17	Advance open-hole with 12.25-in. tricone bit.
87.0	4/25/00	Tue	N	18:00	23:59				5:59		Clean hole.
87.0	4/26/00	Wed.	N	0:01	0:53				0:52		Work to unplug bit.
87.0	4/26/00	Wed.	N	0:53	1:30	1722.00	1642.00	80.00	0:37	129.73	Trip out 7-in. drill rods.
87.0	4/26/00	Wed.	N	2:00	6:00	1642.00	1722.00	80.00	4:00	20.00	Clean hole.
87.0	4/26/00	Wed.	D	8:00	15:00	1682.00	0.00	1682.00	7:00	240.29	Trip out 7-in. drill rods.
87.0	4/26/00	Wed.	D	16:44							Use transducer to measure DTW at 1237.97 ft bgs.
88.0	4/26/00	Wed.	N	19:00	23:59	722.00	522.00	200.00	4:59	40.13	Trip out 13 5/8-in. casing.
88.0	4/27/00	Thu	N	0:10	5:00	522.00	0.00	522.00	4:50	108.00	Trip out 13 5/8-in. casing.

CdV-R-15-3 Operations Chronology (continued)

12-hr Shift	Date	Day	Shift	From (time)	To (time)	Prod. From	Prod. To	Prod. (ft)	Time (hr:min)	Rate (ft/hr)	Activity
89.0	4/27/00	Thu	D	8:00	11:30				3:30		Run borehole video log.
89.0	4/27/00	Thu	D	11:30	12:00				0:30		Use transducer to measure DTW = 1238.34 ft.
89.0	4/27/00	Thu	D	12:00	17:00				5:00		DX evacuation drill.
90.0	4/27/00	Thu	N	18:00	21:00				3:00		Pull transducer and run natural gamma tool.
90.0	4/27/00	Thu	N	21:00	23:59				2:59		Move completion materials on-site.
90.0	4/28/00	Fri	N	0:01	6:00				5:59		Move completion materials on-site.
91.0	4/28/00	Fri	D	8:00	18:00				10:00		Schlumberger on-site running geophysical logs.
92.0	4/28/00	Fri	N	18:00	22:00				4:00		Schlumberger on-site running geophysical logs.
93.0	4/29/00	Sat	D	8:10	14:25				6:15		Schlumberger on-site running geophysical logs.
93.0	4/29/00	Sat	D	14:25	18:00				3:35		Move completion materials on-site.
94.0	4/29/00	Sat	N	18:00	23:59				5:59		Move completion materials on-site.
94.0	4/30/00	Sun	N	0:01	6:00				5:59		Move completion materials on-site.
95.0	4/30/00	Sun	D	6:00	18:00				12:00		Move completion materials on-site.
96.0	4/30/00	Sun	N	18:00	23:59				5:59		Move completion materials on-site.
96.0	5/1/00	Mon	N	0:01	6:00				5:59		Move completion materials on-site.
97.0	5/1/00	Mon	D	6:00	18:00				12:00		Move completion materials on-site.
98.0	5/1/00	Mon	N	18:00	21:10				3:10		Run borehole video log with the 4-in. camera.
98.0	5/1/00	Mon	N	21:10	23:05				1:55		Set up to trip in tremie.
98.0	5/1/00	Mon	N	23:05	23:59	0.00	362.00	362.00	0:54	402.22	Trip in B rods.
98.0	5/2/00	Tue	N	0:01	3:30	362.00	1670.00	1308.00	3:29	375.50	Trip in B rods.
98.0	5/2/00	Tue	N	3:30	6:00				2:30		Prepare to cement bottom of the hole.
99.0	5/2/00	Tue	D	7:00	9:47				2:47		Mix and pump cement into bottom of borehole.
99.0	5/2/00	Tue	D	10:00	11:30				1:30		Lay out and measure well casing.
99.0	5/2/00	Tue	D	11:30	12:20				0:50		Trip in well casing.
99.0	5/2/00	Tue	D	13:00	17:45				4:45		Trip in well casing.
100.0	5/2/00	Tue	N	18:30	23:59				5:29		Trip in well casing.
100.0	5/3/00	Wed.	N	0:01	6:00				5:59		Trip in well casing.
101.0	5/3/00	Wed.	N	18:00	23:59				5:59		Trip in well casing.
101.0	5/4/00	Thu	N	0:01	1:30				1:29		Land the well on the conductor casing.
101.0	5/4/00	Thu	N	1:30	6:00				4:30		Set up to backfill.
102.0	5/4/00	Thu	D	7:10	18:00				10:50		Backfill borehole TD to 1678 ft.

CdV-R-15-3 Operations Chronology (continued)

12-hr Shift	Date	Day	Shift	From (time)	To (time)	Prod. From	Prod. To	Prod. (ft)	Time (hr:min)	Rate (ft/hr)	Activity
103.0	5/4/00	Thu	N	18:00	23:59				5:59		Backfill borehole 1678 to 1605 ft.
103.0	5/5/00	Fri	N	0:01	6:00				5:59		Backfill borehole 1605 to 1531 ft.
104.0	5/5/00	Fri	D	6:00	17:20				11:20		Backfill borehole 1531 to 1490 ft.
105.0	5/6/00	Sat	D	12:00	18:00				6:00		Backfill borehole 1490 to 1414 ft.
106.0	5/6/00	Sat	N	18:00	23:59				5:59		Backfill borehole 1414 to 1282 ft.
106.0	5/7/00	Sun	N	0:01	4:30				4:29		Backfill borehole 1282 to 1075 ft.
107.0	5/7/00	Sun	D	7:30	10:30				3:00		Backfill borehole 1075 to 1045 ft.
N/A	05/07-5/31	-	-								Cerro Grande fire—shut down.
108.0	6/1/00	Thu	D	9:30	11:48				2:18		Backfill borehole 1045 to 974 ft.
108.0	6/1/00	Thu	D	11:48	12:14				0:26		Work to unplug tremie.
108.0	6/1/00	Thu	D	12:45	15:25				2:40		Trip out B rods; 440 ft of plugged tremie.
108.0	6/1/00	Thu	D	15:25	17:30	0.00	600.00	600.00	2:05	288.00	Trip in tremie while clearing plug.
109.0	6/2/00	Fri	D	10:00	15:45				5:45		Backfill borehole 974 to 875 ft.
110.0	6/5/00	Mon	D	7:00	15:15				8:15		Backfill borehole 875 to 696 ft.
111.0	6/6/00	Tue	D	7:15	18:00				10:45		Backfill borehole 696 to 620 ft.
112.0	6/6/00	Tue	N	18:00	23:59				5:59		Backfill borehole 620 to 596 ft.
112.0	6/7/00	Wed.	N	0:01	5:15				5:14		Backfill borehole 596 to 490 ft.
113.0	6/7/00	Wed.	D	6:45	17:30				10:45		Backfill borehole 490 to 279 ft.
114.0	6/7/00	Wed.	N	19:30	23:59				4:29		Backfill borehole 279 to 134 ft.
114.0	6/8/00	Thu	N	0:01	5:15				5:14		Backfill borehole 134 to 77 ft.
115.0	6/8/00	Thu	D	8:00	12:00				4:00		Begin land applying water.
115.0	6/8/00	Thu	D	12:00	16:00				4:00		Add cement to bring cement up 30 ft.
116.0	6/9/00	Fri	D	7:30	14:30				7:00		Continue water discharge, add cement from 74 ft to 20 ft bgs.
N/A	6/12/00	Mon	D	9:00	18:00				9:00		Steam clean equipment.
N/A	6/13/00	Tue	D	6:00	18:00				12:00		Steam clean equipment.
117.0	6/15/00	Thu	D	6:00	18:00				12:00		Demobilize.
118.0	6/16/00	Fri	D	6:00	18:00				12:00		Demobilize.
119.0	6/19/00	Mon	D	6:00	18:00				12:00		Demobilize.
120.0	6/20/00	Tue	D	12:00	15:00				3:00		Cement in upper 20 ft of borehole and jack cellar.
121.0	7/27/00	Thu	D	9:15	12:15				3:00		Downhole video log of cased well.

CdV-R-15-3 Operations Chronology (continued)

12-hr Shift	Date	Day	Shift	From (time)	To (time)	Prod. From	Prod. To	Prod. (ft)	Time (hr:min)	Rate (ft/hr)	Activity
122.0	7/28/00	Fri	D	6:00	15:15				9:15		Mobilize.
122.0	7/28/00	Fri	D	15:15	17:00	0.00	600.00	600.00	1:45	342.86	Scrub with wire brush on N rods.
123.0	7/29/00	Sat	D	6:30	10:50				4:20		Scrub with wire brush on N rods.
123.0	7/29/00	Sat	D	11:10	17:30				6:20		Develop well with bailer.
124.0	7/30/00	Sun	D	6:15	10:45				4:30		Develop well with bailer.
124.0	7/30/00	Sun	D	11:00	13:20	0.00	1670.00	1670.00	2:20	715.71	Trip in core rod on N rods to clean sump.
124.0	7/30/00	Sun	D	13:25	14:15	1670.00	0.00	1670.00	0:50	2004.00	Trip out core rods. No material in sump.
124.0	7/30/00	Sun	D	14:50	17:30				2:40		Develop well with bailer.
125.0	7/31/00	Mon	D	7:30	9:00	0.00	1262.00	1262.00	1:30	841.33	Trip in 10 hp pump for development.
125.0	7/31/00	Mon	D	9:30	18:10				8:40		Pump develop screen #4.
126.0	8/1/00	Tue	D	7:15	10:04				2:49		Pump develop screen #4.
126.0	8/1/00	Tue	D	10:04	10:16				0:12		Lower pump to screen #5.
126.0	8/1/00	Tue	D	10:16	17:37				7:21		Pump develop screen #5.
127.0	8/2/00	Wed.	D	6:50	8:20				1:30		Pump develop screen #5.
127.0	8/2/00	Wed.	D	8:20	9:22				1:02		Move pump to screen #4 for a screening sample.
127.0	8/2/00	Wed.	D	9:22	9:50	1294.00	1638.00	344.00	0:28	737.14	Lower pump to screen #6.
127.0	8/2/00	Wed.	D	9:50	16:30				6:40		Pump develop screen #6.
128.0	8/3/00	Thu	D	7:00	17:45				10:45		Pump develop screen #6 and sump.
129.0	8/4/00	Fri	D	7:00	12:12				5:12		Pump develop sump.
129.0	8/4/00	Fri	D	12:30	13:45	1670.00	0.00	1670.00	1:15	1336.00	Trip out pump on N rods.
129.0	8/4/00	Fri	D	14:00	15:10				1:10		Set up for hydrologic testing.
130.0	8/7/00	Mon	D	7:00	8:45	0.00	1630.00	1630.00	1:45	931.43	Trip straddle packers on N rods.
130.0	8/7/00	Mon	D	9:00	17:30				8:30		Hydrologic testing of screen #6.
131.0	8/8/00	Tue	D	9:10	18:50				9:40		Hydrologic testing of screens #4 and #5.
132.0	8/9/00	Wed.	D	7:10	8:30				1:20		Hydrologic testing of screen #5.
132.0	8/9/00	Wed.	D	8:30	16:00				7:30		Mobilize equipment to R-19 drill site.
133.0	8/10/00	Thu	D	11:05	15:00				3:55		Video log of cased well.
134.0	8/11/00	Fri	D	9:30	12:45				3:15		Natural gamma log of cased well.
135.0	8/24/00	Thu	D	8:00	17:30				9:30		Retest screen #6.
136.0	8/25/00	Fri	D	7:00	11:30				4:30		Retest screen #5.
136.0	8/25/00	Fri	D	12:00	17:30				5:30		Set to measure water levels in screen #3.

CdV-R-15-3 Operations Chronology (continued)

12-hr Shift	Date	Day	Shift	From (time)	To (time)	Prod. From	Prod. To	Prod. (ft)	Time (hr:min)	Rate (ft/hr)	Activity
136.0	8/25/00	Fri	D						0:00		
136.0	8/25/00	Fri	D						0:00		

Appendix B

Lithologic Log

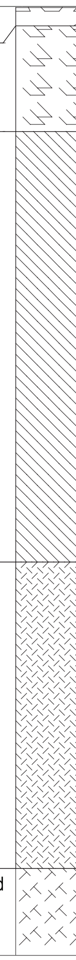
LOS ALAMOS NATIONAL LABORATORY
ENVIRONMENTAL RESTORATION PROJECT,
REMEDIAL ACTIONS FOCUS AREA
BOREHOLE LOG

BOREHOLE ID: CdV-R15-3	TA/OU: TA-15	Page 1 of 7
DRILLING COMPANY: Stewart Bro./Dynatec	Start Date: 3/17/00	Finish Date: 4/25/00
DRILLING EQ/METHOD: CME-750/Foremost DR24	SAMPLING EQ/METHOD: None	
GROUND ELEVATION: 7258.9 ft	GEOLOGY P.I.: Vaniman	TOTAL DEPTH = 1722 ft bgs
DRILLER: Johnson/Brown,Thoren, Wilson, Woodward		SITE GEOLOGIST: Everett

Depth (ft)	Elevation (ft)	Core Run # (amt. recov./amt. attemp.)	Core Run	Cuttings Collected	Geologic Property (Geologic) and Archived (Moisture-Protected HSA Core)	Moisture/Matric Pot.	Lithology	Graphic Log	Lithologic Symbol
0–5		N/A				N/A	ALLUVIUM: (0–5 ft) Inclusion of rubbish indicates excavation and refilling.		
5–34							Qbt 4, TSHIREGE MEMBER, BANDELIER TUFF: (5–34 ft) Tuff with grayish-brown (5YR 3/2) matrix with rare pumice; abundant feldspar and quartz phenocrysts, few lithic fragments.		Qbt 4
34–152							Qbt 3, TSHIREGE MEMBER, BANDELIER TUFF: (34–152 ft) Poorly welded devitrified tuff with abundant feldspar and quartz phenocrysts, medium-light gray (N6).		Qbt 3
152–236							Qbt 2, TSHIREGE MEMBER, BANDELIER TUFF: (152–236 ft) Moderately welded devitrified tuff with abundant feldspar and quartz phenocrysts, grayish orange-pink (5YR 7/2).		Qbt 2
236–255							Qbt 1v, TSHIREGE MEMBER, BANDELIER TUFF: (236–290 ft) Nonwelded devitrified tuff with abundant feldspar and quartz phenocrysts.		

Depth (ft): 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190 195 200 205 210 215 220 225 230 235 240 245 250 255

Elevation (ft): 7255 7250 7245 7240 7235 7230 7225 7220 7215 7210 7205 7200 7195 7190 7185 7180 7175 7170 7165 7160 7155 7150 7145 7140 7135 7130 7125 7120 7115 7110 7105 7100 7095 7090 7085 7080 7075 7070 7065 7060 7055 7050 7045 7040 7035 7030 7025 7020 7015 7010 7005



LOS ALAMOS NATIONAL LABORATORY
ENVIRONMENTAL RESTORATION PROJECT,
REMEDIAL ACTIONS FOCUS AREA
BOREHOLE LOG

BOREHOLE ID: CdV-R15-3	TA/OU: TA-15	Page 2 of 7
DRILLING COMPANY: Stewart Bro./Dynatec	Start Date: 3/17/00	Finish Date: 4/25/00
DRILLING EQ/METHOD: CME-750/Foremost DR24	SAMPLING EQ/METHOD: None	
GROUND ELEVATION: 7258.9 ft	GEOLOGY P.I.: Vaniman	TOTAL DEPTH = 1722 ft bgs
DRILLER: Johnson/Brown,Thoren, Wilson, Woodward		SITE GEOLOGIST: Everett

Depth (ft)	Elevation (ft)	Core Run # (amt. recov./amt. attemp.)	Core Run	Cuttings Collected	Geologic Property (Geologic) and Archived (Moisture-Protected HSA Core)	Moisture/Matric Pot.	Lithology	Graphic Log	Lithologic Symbol
260–290	7000–6970						Qbt 1v, TSHIREGE MEMBER, BANDELIER TUFF: (236–290 ft) Nonwelded devitrified tuff with abundant feldspar and quartz phenocrysts.		Qbt 1v
290–350	6970–6910						Qbt 1g, TSHIREGE MEMBER, BANDELIER TUFF: (290–350 ft) Nonwelded vitric tuff with abundant feldspar and quartz phenocrysts.		Qbt 1g
350–362	6910–6898						Qbt t, TSANKAWI PUMICE BED OF THE TSHIREGE MEMBER, BANDELIER TUFF: (350–362 ft) Vitric pumice fall; pumice fragmented in cuttings, abundant quartz and feldspar phenocrysts.		Qbt t
362–515	6898–6745				Geologic (372–377 ft) Geologic (467–472 ft)		Qct, CERRO TOLEDO INTERVAL: (362–582 ft) Predominantly sand and gravels comprised of detritus from intermediate-composition lavas. Clasts coarser than fine gravel size (2–64 mm) are rare. Lower section from 572 to 582 ft appears to be reworked Otowi Member of the Bandelier Tuff mixed with Cerro Toledo detritus (based on intermixed fragments of porphyritic pumice and rise in natural gamma log).		Qct

Depth (ft)	Elevation (ft)
260	7000
265	6995
270	6990
275	6985
280	6980
285	6975
290	6970
295	6965
300	6960
305	6955
310	6950
315	6945
320	6940
325	6935
330	6930
335	6925
340	6920
345	6915
350	6910
355	6905
360	6900
365	6895
370	6890
375	6885
380	6880
385	6875
390	6870
395	6865
400	6860
405	6855
410	6850
415	6845
420	6840
425	6835
430	6830
435	6825
440	6820
445	6815
450	6810
455	6805
460	6800
465	6795
470	6790
475	6785
480	6780
485	6775
490	6770
495	6765
500	6760
505	6755
510	6750
515	6745

LOS ALAMOS NATIONAL LABORATORY
ENVIRONMENTAL RESTORATION PROJECT,
REMEDIAL ACTIONS FOCUS AREA
BOREHOLE LOG

BOREHOLE ID: CdV-R15-3	TA/OU: TA-15	Page 3 of 7
DRILLING COMPANY: Stewart Bro./Dynatec	Start Date: 3/17/00	Finish Date: 4/25/00
DRILLING EQ/METHOD: CME-750/Foremost DR24	SAMPLING EQ/METHOD: None	
GROUND ELEVATION: 7258.9 ft	GEOLOGY P.I.: Vaniman	TOTAL DEPTH = 1722 ft bgs
DRILLER: Johnson/Brown,Thoren, Wilson, Woodward		SITE GEOLOGIST: Everett

Depth (ft)	Elevation (ft)	Core Run # (amt. recov./amt. attemp.)	Core Run	Cuttings Collected	Geologic Property (Geologic) and Archived (Moisture-Protected HSA Core)	Moisture/Matric Pot.	Lithology	Graphic Log	Lithologic Symbol
520–582	6740–6680			Collected	Geologic (572–577 ft)		Qct, CERRO TOLEDO INTERVAL: (362–582 ft) Predominantly sand and gravels comprised of detritus from intermediate-composition lavas. Clasts coarser than fine gravel size (2–64 mm) are rare. Lower section from 572 to 582 ft appears to be reworked Otowi Member of the Bandelier Tuff mixed with Cerro Toledo detritus (based on intermixed fragments of porphyritic pumice and rise in natural gamma log).		Qct
582–750	6680–6510			Collected	Geologic (617–622 ft)		Qbo, OTOWI MEMBER, BANDELIER TUFF: (582–750 ft) Nonwelded vitric tuff with abundant feldspar and quartz phenocrysts. Possible perched water noted at 598–611 ft during drilling; unconfirmed when examined with borehole video.		Qbo
750–770	6510–6490			Collected			Qbo g, GUAJE PUMICE BED OF THE OTOWI MEMBER, BANDELIER TUFF: (750–800 ft) Vitric pumice fall; pumice fragmented in cuttings, abundant quartz, and feldspar phenocrysts.		

Depth (ft)	Elevation (ft)
520	6740
525	6735
530	6730
535	6725
540	6720
545	6715
550	6710
555	6705
560	6700
565	6695
570	6690
575	6685
580	6680
585	6675
590	6670
595	6665
600	6660
605	6655
610	6650
615	6645
620	6640
625	6635
630	6630
635	6625
640	6620
645	6615
650	6610
655	6605
660	6600
665	6595
670	6590
675	6585
680	6580
685	6575
690	6570
695	6565
700	6560
705	6555
710	6550
715	6545
720	6540
725	6535
730	6530
735	6525
740	6520
745	6515
750	6510
755	6505
760	6500
765	6495
770	6490

LOS ALAMOS NATIONAL LABORATORY
ENVIRONMENTAL RESTORATION PROJECT,
REMEDIAL ACTIONS FOCUS AREA
BOREHOLE LOG

BOREHOLE ID: CdV-R15-3	TA/OU: TA-15	Page 4 of 7
DRILLING COMPANY: Stewart Bro./Dynatec	Start Date: 3/17/00	Finish Date: 4/25/00
DRILLING EQ/METHOD: CME-750/Foremost DR24	SAMPLING EQ/METHOD: None	
GROUND ELEVATION: 7258.9 ft	GEOLOGY P.I.: Vaniman	TOTAL DEPTH = 1722 ft bgs
DRILLER: Johnson/Brown,Thoren, Wilson, Woodward		SITE GEOLOGIST: Everett

Depth (ft)	Elevation (ft)	Core Run # (amt. recov./amt. attemp.)	Core Run	Cuttings Collected	Geologic Property (Geologic) and Archived (Moisture-Protected HSA Core)	Moisture/Matric Pot.	Lithology	Graphic Log	Lithologic Symbol
775	6485						Qbo g, GUAJE PUMICE BED OF THE OTOWI MEMBER, BANDELIER TUFF: (750–800 ft) Vitric pumice fall; pumice fragmented in cuttings, abundant quartz, and feldspar phenocrysts.		Qbo g
780	6480								
785	6475								
790	6470								
795	6465								
800	6460						Tpf, PUYE FORMATION, FANGLOMERATE FACIES: (800–963 ft) Sand and gravel of intermediate volcanic composition. Spectral gamma log indicates relatively high K and Th composition. Borehole video indicates that coarse cobbles exceeding the borehole diameter (~30 cm) are present.		
805	6455								
810	6450								
815	6445								
820	6440								
825	6435				Geologic (822–827 ft)				
830	6430								
835	6425								
840	6420								
845	6415								
850	6410								
855	6405								
860	6400								
865	6395								
870	6390								
875	6385								
880	6380								
885	6375								
890	6370								
895	6365								
900	6360								
905	6355								Tpf
910	6350								
915	6345								
920	6340								
925	6335								
930	6330								
935	6325								
940	6320								
945	6315								
950	6310								
955	6305				Geologic (952–957 ft)				
960	6300								
965	6295						Tb4, CERROS DEL RIO LAVAS (DACITIC): (963–980 ft) Dacitic scoria and lava with plagioclase and pyroxene phenocrysts. Borehole video indicates flow-top rubble from 963 to 966 ft and massive flow from 966 to 987 ft.		
970	6290				Geologic (967–972 ft)				
975	6285				Geologic (972–977 ft)				Tb
980	6280								
985	6275				Geologic (982–987 ft)				
990	6270								
995	6265								
1000	6260								
1005	6255				Geologic (1002–1007 ft)				Tb
1010	6250								

LOS ALAMOS NATIONAL LABORATORY
ENVIRONMENTAL RESTORATION PROJECT,
REMEDIAL ACTIONS FOCUS AREA
BOREHOLE LOG

BOREHOLE ID: CdV-R15-3	TA/OU: TA-15	Page 5 of 7
DRILLING COMPANY: Stewart Bro./Dynatec	Start Date: 3/17/00	Finish Date: 4/25/00
DRILLING EQ/METHOD: CME-750/Foremost DR24	SAMPLING EQ/METHOD: None	
GROUND ELEVATION: 7258.9 ft	GEOLOGY P.I.: Vaniman	TOTAL DEPTH = 1722 ft bgs
DRILLER: Johnson/Brown,Thoren, Wilson, Woodward		SITE GEOLOGIST: Everett

Depth (ft)	Elevation (ft)	Core Run # (amt. recov./amt. attemp.)	Core Run	Cuttings Collected	Geologic Property (Geologic) and Archived (Moisture-Protected HSA Core)	Moisture/Matric Pot.	Lithology	Graphic Log	Lithologic Symbol
1015	6245						Tpf, PUYE FORMATION, FANGLOMERATE FACIES: (1012–1207 ft) Gravel and coarse sand from dacitic and other intermediate volcanic sources. Borehole video indicates coarsest cobbles are ~15–30 cm in diameter. Spectral gamma log indicates relatively high K and Th composition from this portion of the Puye to ~1246-ft depth.		
1020	6240								
1025	6235								
1030	6230								
1035	6225								
1040	6220								
1045	6215								
1050	6210								
1055	6205								Tp
1060	6200								
1065	6195								
1070	6190								
1075	6185								
1080	6180								
1085	6175								
1090	6170								
1095	6165								
1100	6160								
1105	6155								
1110	6150								
1115	6145								
1120	6140								
1125	6135								
1130	6130								
1135	6125								
1140	6120								
1145	6115								
1150	6110								
1155	6105								Tp
1160	6100								
1165	6095								
1170	6090								
1175	6085								
1180	6080								
1185	6075								
1190	6070								
1195	6065								
1200	6060								
1205	6055								
1210	6050						Tpf, PUYE FORMATION, FANGLOMERATE FACIES: (1207–1232 ft) Medium to fine sand from dacitic and other intermediate volcanic sources. Borehole video indicates coarsest cobbles are ~10 cm in diameter.		
1215	6045								
1220	6040								
1225	6035								Tp
1230	6030								
1235	6025						Tpf, PUYE FORMATION, FANGLOMERATE FACIES: (1232–1262 ft) Gravel and coarse sand from dacitic and other intermediate volcanic sources. Borehole video indicates washouts. Spectral gamma log indicates transition to lower K and Th sediments occurs at ~1246-ft depth within this interval and persisting to ~1518-ft depth.		
1240	6020								
1245	6015								
1250	6010								
1255	6005								Tp
1260	6000								

LOS ALAMOS NATIONAL LABORATORY
ENVIRONMENTAL RESTORATION PROJECT,
REMEDIAL ACTIONS FOCUS AREA
BOREHOLE LOG

BOREHOLE ID: CdV-R15-3	TA/OU: TA-15	Page 6 of 7
DRILLING COMPANY: Stewart Bro./Dynatec	Start Date: 3/17/00	Finish Date: 4/25/00
DRILLING EQ/METHOD: CME-750/Foremost DR24	SAMPLING EQ/METHOD: None	
GROUND ELEVATION: 7258.9 ft	GEOLOGY P.I.: Vaniman	TOTAL DEPTH = 1722 ft bgs
DRILLER: Johnson/Brown,Thoren, Wilson, Woodward		SITE GEOLOGIST: Everett

Depth (ft)	Elevation (ft)	Core Run # (amt. recov./amt. attemp.)	Core Run	Cuttings Collected	Geologic Property (Geologic) and Archived (Moisture-Protected HSA Core)	Moisture/Matric Pot.	Lithology	Graphic Log	Lithologic Symbol
1265	5995						Tpf, PUYE FORMATION, FANGLOMERATE FACIES: (1262–1272 ft) Medium to fine sand from dacitic and other intermediate volcanic sources.		
1270	5990								
1275	5985				Geologic (1272–1277 ft)		Tpf, PUYE FORMATION, FANGLOMERATE FACIES: (1272–1282 ft) Gravel and coarse sand from dacitic and other intermediate volcanic sources.		
1280	5980								
1285	5975						Tpf, PUYE FORMATION, FANGLOMERATE FACIES: (1282–1317 ft) Medium to fine sand from dacitic and other intermediate volcanic sources.		
1290	5970								
1295	5965								
1300	5960								
1305	5955								Tp
1310	5950								
1315	5945								
1320	5940						Tpf, PUYE FORMATION, FANGLOMERATE FACIES: (1317–1367 ft) Gravel and coarse sand from dacitic and other intermediate volcanic sources. Borehole video indicates washouts.		
1325	5935								
1330	5930								
1335	5925								
1340	5920								
1345	5915								
1350	5910				Geologic (1347–1352 ft)				
1355	5905								Tp
1360	5900								
1365	5895								
1370	5890						Tpf, PUYE FORMATION, FANGLOMERATE FACIES: (1367–1402 ft) Matrix of medium to fine sand from dacitic and other intermediate volcanic sources; borehole video indicates coarse cobbles up to 30 cm and several washouts.		
1375	5885								
1380	5880								
1385	5875								
1390	5870								
1395	5865								
1400	5860								
1405	5855						Tpf, PUYE FORMATION, FANGLOMERATE FACIES: (1402–1407 ft) Lens of coarse sand from dacitic and other intermediate volcanic sources.		Tp
1410	5850						Tpf, PUYE FORMATION, FANGLOMERATE FACIES: (1407–1417 ft) Medium to fine sand from dacitic and other intermediate volcanic sources.		
1415	5845								
1420	5840						Tpf, PUYE FORMATION, FANGLOMERATE FACIES: (1417–1427 ft) Very fine-grained sediment from dacitic and other intermediate volcanic sources; possible ash.		
1425	5835								
1430	5830						Tpf, PUYE FORMATION, FANGLOMERATE FACIES: (1427–1442 ft) Medium to fine sand from dacitic and other intermediate volcanic sources.		
1435	5825								
1440	5820								
1445	5815						Tpf, PUYE FORMATION, FANGLOMERATE FACIES: (1442–1447 ft) Gravel and coarse sand from dacitic and other intermediate volcanic sources.		
1450	5810				Geologic (1447–1452 ft)		Tpf, PUYE FORMATION, FANGLOMERATE FACIES: (1447–1452 ft) Fine-grained sediment from dacitic and other intermediate volcanic sources.		
1455	5805						Tpf, PUYE FORMATION, FANGLOMERATE FACIES: (1452–1467 ft) Gravel and coarse sand from dacitic and other intermediate volcanic sources.		Tp
1460	5800								
1465	5795								

LOS ALAMOS NATIONAL LABORATORY
ENVIRONMENTAL RESTORATION PROJECT,
REMEDIAL ACTIONS FOCUS AREA
BOREHOLE LOG

BOREHOLE ID: CdV-R15-3	TA/OU: TA-15	Page 7 of 7
DRILLING COMPANY: Stewart Bro./Dynatec	Start Date: 3/17/00	Finish Date: 4/25/00
DRILLING EQ/METHOD: CME-750/Foremost DR24	SAMPLING EQ/METHOD: None	
GROUND ELEVATION: 7258.9 ft	GEOLOGY P.I.: Vaniman	TOTAL DEPTH = 1722 ft bgs
DRILLER: Johnson/Brown,Thoren, Wilson, Woodward		SITE GEOLOGIST: Everett

Depth (ft)	Elevation (ft)
1470	5790
1475	5785
1480	5780
1485	5775
1490	5770
1495	5765
1500	5760
1505	5755
1510	5750
1515	5745
1520	5740
1525	5735
1530	5730
1535	5725
1540	5720
1545	5715
1550	5710
1555	5705
1560	5700
1565	5695
1570	5690
1575	5685
1580	5680
1585	5675
1590	5670
1595	5665
1600	5660
1605	5655
1610	5650
1615	5645
1620	5640
1625	5635
1630	5630
1635	5625
1640	5620
1645	5615
1650	5610
1655	5605
1660	5600
1665	5595
1670	5590
1675	5585
1680	5580
1685	5575
1690	5570
1695	5565
1700	5560
1705	5555
1710	5550
1715	5545
1720	5540

Core Run # (amt. recov./amt. attemp.)	Core Run	Cuttings Collected	Geologic Property (Geologic) and Archived (Moisture-Protected HSA Core)	Moisture/Matric Pot.	Lithology	Graphic Log	Lithologic Symbol
					Tpf, PUYE FORMATION, FANGLOMERATE FACIES: (1467–1492 ft) Fine-grained sediment from dacitic and other intermediate volcanic sources.		
					Tpf, PUYE FORMATION, FANGLOMERATE FACIES: (1492–1507 ft) Gravel and coarse sand from dacitic and other intermediate volcanic sources.		Tp
					Tpf, PUYE FORMATION, FANGLOMERATE FACIES: (1507–1517 ft) Fine-grained sediment from dacitic and other intermediate volcanic sources. Bottom of this unit marks transition to pumiceous sediments of higher K and Th content in the spectral gamma log.		
					Tpf, PUYE FORMATION, FANGLOMERATE FACIES (PUMICEOUS): (1518–1527 ft) Minor gravel and coarse sand from dacitic and rhyo-dacitic volcanic sources. Top of this unit marks transition to pumiceous sediments of higher K and Th content in the spectral gamma log that persist to ~1640-ft depth.		Tp
					Tpf, PUYE FORMATION, FANGLOMERATE FACIES (PUMICEOUS): (1527–1562 ft) Gravel with pumice and ash in medium sand/silt matrix, from dacitic and rhyodacitic volcanic sources. Borehole video from 1530 ft to deepest image (1679 ft) indicates greater abundance of coarse cobbles (>30 cm) in poorly cemented (washed-out) matrix.		
			Geologic (1592–1597 ft)		Tpf, PUYE FORMATION, FANGLOMERATE FACIES (PUMICEOUS): (1562–1612 ft) Gravel from dacitic and rhyodacitic volcanic sources.		Tp
					Tpf, PUYE FORMATION, FANGLOMERATE FACIES (PUMICEOUS): (1612–1622 ft) Gravel and coarse sand with pumice, from dacitic and rhyodacitic volcanic sources.		
			Geologic (1642–1647 ft)		Tpf, PUYE FORMATION, FANGLOMERATE FACIES (PUMICEOUS): (1622–1647 ft) Gravel and coarse sand with vitric pumice, from dacitic and rhyodacitic volcanic sources. Spectral gamma log indicates transition to lower K and Th sediments occurs at ~1640-ft depth within this interval and persists to deepest spectral gamma log reading (1679 ft).		Tp
					Tpf, PUYE FORMATION, FANGLOMERATE FACIES (PUMICEOUS): (1647–1652 ft) Gravel and coarse sand with vitric pumice, from dacitic and rhyodacitic volcanic sources.		
			Geologic (1717–1722 ft)		Tpf, PUYE FORMATION, FANGLOMERATE FACIES (PUMICEOUS): (1652–1722 ft) Gravel and coarse sand from dacitic and rhyodacitic volcanic sources; rare pumice.		Tp

Appendix C

Thin-Section Petrographic Descriptions from CdV-R-15-3

Sample	Description
CDV-R15 372–377	Cerro Toledo. Section contains 21 fragments of 2–4 mm sieve size. Varied lithologies include highly altered silicic to intermediate lavas (n=9), sparsely quartz-sanidine porphyritic vitric pumice (n=5), plagioclase-clinopyroxene intermediate lavas (n=2), plagioclase-amphibole intermediate lavas (n=2), trachytic plagioclase-amphibole intermediate lava (n=1), plagioclase-biotote-clinopyroxene intermediate lava (n=1), and a cluster of clay-bonded sparsely albite-porphyritic pumices (n=1).
CDV-R15 467–472	Cerro Toledo. Section contains 32 fragments of 2–4 mm sieve size. Varied lithologies include highly silicified lavas with opal-lined voids (n=11), aphyric to sparsely quartz-sanidine porphyritic vitric pumice (n=9), plagioclase-clinopyroxene intermediate lavas (n=5), pumice extensively altered to clay and silica or zeolites (n=3), quartz-biotite intermediate lava (n=1), hematite-altered red lava (n=1), heavily altered plagioclase-amphibole lava (n=1), and devitrified aphyric lava with abundant trichites (n=1).
CDV-R15 572–577	Cerro Toledo. Section contains 39 fragments of 2–4 mm sieve size. Varied lithologies include plagioclase-clinopyroxene intermediate lavas with fine-grained to glassy matrix (n=11), altered and oxidized intermediate lavas with clay alteration of feldspars (n=10), feldspathic intermediate lavas with randomly oriented to strongly flow-oriented plagioclase laths and no prominent phenocrysts (n=9), aphyric to sparsely quartz-sanidine-albite porphyritic vitric pumice (n=4), plagioclase-amphibole intermediate lavas with heavily oxidized amphibole (n=4), and sandstone of strained quartz grains in micaceous matrix (n=1).
CDV-R15 617–622	Otowi. Section contains 34 fragments of 2–4 mm sieve size, most consisting of vitric non-welded sanidine-quartz porphyritic pumice (n=28); the remainder comprised of felsic intermediate lavas (n=4), highly silicified intermediate lava (n=1), and arkosic quartz-plagioclase-microcline sandstone (n=1).
CDV-R15 822–827	Upper Puye. Section contains 29 fragments of 2–4 mm sieve size. Varied lithologies include plagioclase-quartz-orthopyroxene±clinopyroxene intermediate lavas (n=13), fine-grained felsic lavas with flow banding and plagioclase±orthopyroxene±clinopyroxene phenocrysts (n=8), highly silicified intermediate lavas (n=4), intermediate lava with acicular orthopyroxene in yellow glass matrix (n=1), intermediate lava with skeletal orthopyroxene microphenocrysts (n=1), plagioclase-amphibole intermediate lava (n=1), and a metamorphic plagioclase-epidote-chlorite lithology (n=1).
CDV-R15 952–957	Upper Puye. Section contains 43 fragments of 2–4 mm sieve size having limited variability in lithology. Dominant lithology is plagioclase-orthopyroxene-clinopyroxene-amphibole intermediate lava with well-preserved orange-yellow amphibole (n=32); remaining fragments comprised of plagioclase-orthopyroxene intermediate lava (n=10) and heavily altered plagioclase-amphibole intermediate lava (n=1).
CDV-R15 967–972	Cerros del Rio. Section contains 36 fragments of 2–4 mm sieve size, principally representing variants of a single lithology. Dominant variant is plagioclase-clinopyroxene-orthopyroxene dacitic lava with possible remnants of reddish oxidized amphibole (n=30); other fragments of this lithology include oxidized dacitic pumice (n=2) and yellow-glass dacitic pumice (n=2). Foreign fragments include a clay-cemented pumice breccia (n=1) and an altered plagioclase-amphibole intermediate lava (n=1).
CDV-R15 972–977	Cerros del Rio. Section contains 9 hand-picked fragments of plagioclase-clinopyroxene-orthopyroxene dacitic lava with possible remnants of reddish oxidized amphibole, similar to the sample at 967–972 ft but with coarser-grained phenocrysts (clinopyroxene to 0.5 mm versus 0.3 mm).
CDV-R15 982–987	Cerros del Rio. Section contains 12 hand-picked fragments of olivine-plagioclase porphyritic basalt. Olivine abundant (~10%), euhedral to subhedral, with iddingsite rims. Plagioclase oscillatory zoned and sieved. Rare rounded quartz xenocrysts.
CDV-R15 1002–1007	Cerros del Rio. Section contains 52 fragments of 2–4 mm sieve size, almost all (n=51) of olivine-plagioclase porphyritic basalt similar to sample at 982–987 ft but coarser-grained (olivine to 0.5 mm versus 0.3 mm) and lacking quartz xenocrysts. There is a single fragment of plagioclase-orthopyroxene intermediate lava.

Sample	Description
CDV-R15 1272–1277	Non-pumiceous Puye. Section contains 16 fragments of 2–4 mm sieve size. All are intermediate lavas of limited variability, including plagioclase-clinopyroxene-orthopyroxene intermediate lava (n=10 of which 8 fragments are crystalline and 2 pumiceous), plagioclase-clinopyroxene-orthopyroxene-amphibole intermediate lava (n=3), plagioclase-amphibole intermediate lava (n=2), and felsic intermediate lava with sparse clinopyroxene phenocrysts (n=1).
CDV-R15 1347–1352	Non-pumiceous Puye. Section contains 33 fragments of 2–4 mm sieve size and of very limited variability. Dominant lithology is plagioclase-clinopyroxene-orthopyroxene dacitic lava similar to the Cerros del Rio lava at 972-977 ft (n=13) but another similar lithology is finer-grained (clinopyroxene to 0.2 mm versus 0.5 mm) and contains amphibole with altered rims in some fragments (n=18). Remaining fragments are of fine-grained felsic orthopyroxene-bearing intermediate lava (n=2).
CDV-R15 1447–1452	Non-pumiceous Puye. Section contains 0.25–1 mm sieve fraction. All fragments are from intermediate lavas, mostly of crystalline matrix material with rare fragments of various-colored glasses (~1%). Fragmental phenocrysts include plagioclase, clinopyroxene, amphibole, and quartz.
CDV-R15 1592–1597	Heterogeneous pumiceous Puye. Section contains 26 fragments of 2-4 mm sieve size and of great variability. Lithologies include plagioclase-clinopyroxene-orthopyroxene intermediate lava with rounded quartz (n=6), fine-grained felsic intermediate lava with rare pyroxene (n=5), fine-grained intermediate lava with acicular amphibole (n=3), fine-grained plagioclase-clinopyroxene-orthopyroxene intermediate lava (n=3), fine-grained intermediate lava with acicular orthopyroxene (n=2), two-pyroxene dacite with clay-altered vitric matrix (n=1), intermediate plagioclase-amphibole lava with orange-red amphibole (n=1), intermediate plagioclase-amphibole-orthopyroxene lava with green amphibole (n=1), intermediate plagioclase-amphibole lava with coarse heavily-altered amphibole (n=1), intermediate plagioclase-biotite lava with partially altered biotite (n=1), heavily altered pumice (n=1), and volcanic sandstone with a clay matrix (n=1).
CDV-R15 1642–1647	Heterogeneous pumiceous Puye. Section contains 25 fragments of 2–4 mm sieve size and of great variability. Lithologies include clay-altered sanidine-quartz porphyritic pumice (n=7), felsic fine-grained intermediate lava (n=5), plagioclase-clinopyroxene-altered amphibole intermediate lavas (n=4), fine-grained plagioclase-orthopyroxene lava with acicular orthopyroxene (n=3), plagioclase-amphibole-quartz intermediate lava (n=2), plagioclase-orthopyroxene vitric-matrix intermediate lava (n=1), coarse-grained plagioclase-orthopyroxene intermediate lava (n=1), fine-grained plagioclase-amphibole intermediate lava with acicular amphibole (n=1), and fine-grained plagioclase-clinopyroxene-orthopyroxene intermediate lava (n=1).
CDV-R15 1717–1722	Heterogeneous pumiceous Puye. Section contains 22 fragments of 2–4 mm sieve size and of great variability. Lithologies include plagioclase-amphibole intermediate lava with acicular altered amphiboles (n=4), plagioclase-quartz-amphibole intermediate lava (n=3), plagioclase-acicular orthopyroxene intermediate lava (n=2), plagioclase-amphibole-acicular orthopyroxene intermediate lava (n=2), plagioclase-biotite-altered amphibole intermediate lava (n=2), fine-grained felsic intermediate lava (n=2), plagioclase-amphibole intermediate lava with euhedral amphiboles (n=1), fine-grained plagioclase-clinopyroxene-orthopyroxene intermediate lava (n=1), plagioclase-biotite intermediate lava (n=1), plagioclase-acicular clinopyroxene-acicular orthopyroxene intermediate lava (n=1), plagioclase-biotite-orthopyroxene intermediate lava (n=1), vitric pumice with plagioclase phenocrysts (n=1), and vitric pumice with amphibole and plagioclase phenocrysts (n=1).

Appendix D

CdV-R-15-3 MP Casing Installation Log

Summary MP Casing Log

Company: LANL
Well: CdV15
Site: TA15
Project: HE Plume Characterization

Job No: WB777
Author: DL

Well Information

Reference Datum: ground level
Elevation of Datum: 0.00 ft.
MP Casing Top: 0.00 ft.
MP Casing Length: 1670.09 ft.

Borehole Depth: 1670.00 ft.
Borehole Inclination: vertical
Borehole Diameter: 12.00 in.

Well Description:
Plastic MP55 System
Other References:
5.0 in ID SS casing+screens: LANL8/11/00
B/F LANL 8/15/00 from Gamma Log 8/11/00
M-Collars 2.5 ft below port top

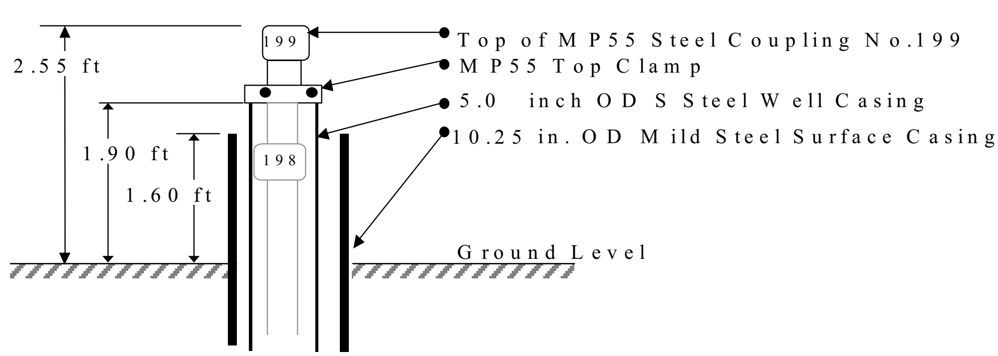
File Information

File Name: 777CV15A.WWD
Report Date: Sun Sep 24 16:25:48 2000

File Date: Sep 24 16:08:23 2000

Sketch of Wellhead Completion

CdV-R15-3 Surface Completion

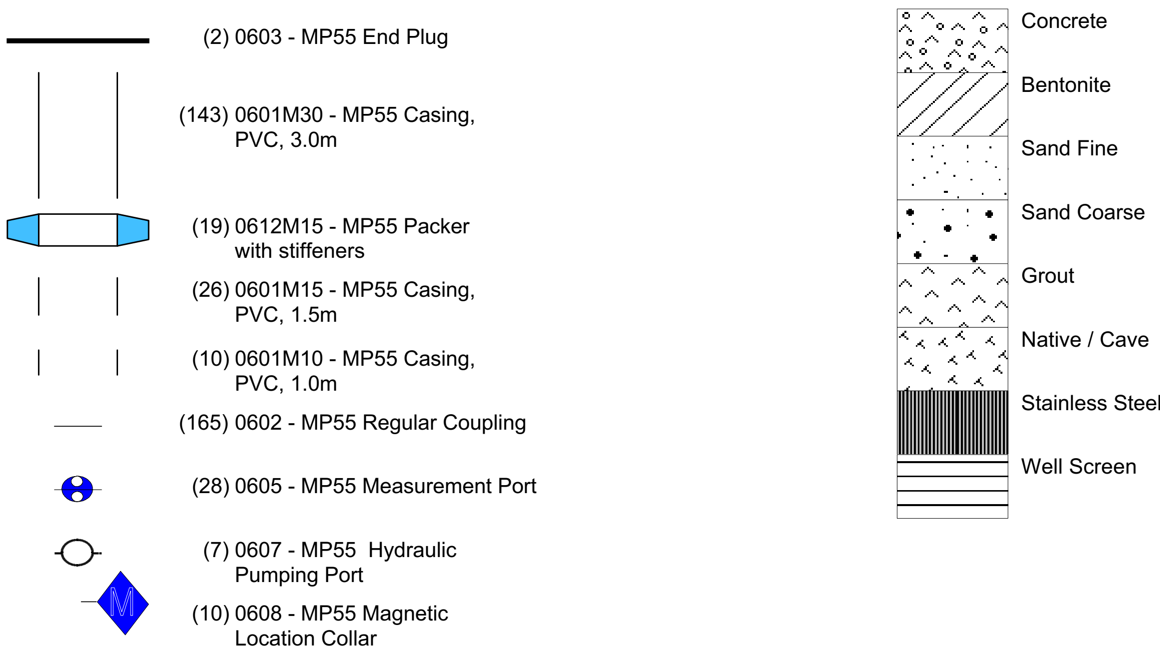


Summary MP Casing Log
LANL

Job No: WB777
Well: CdV15

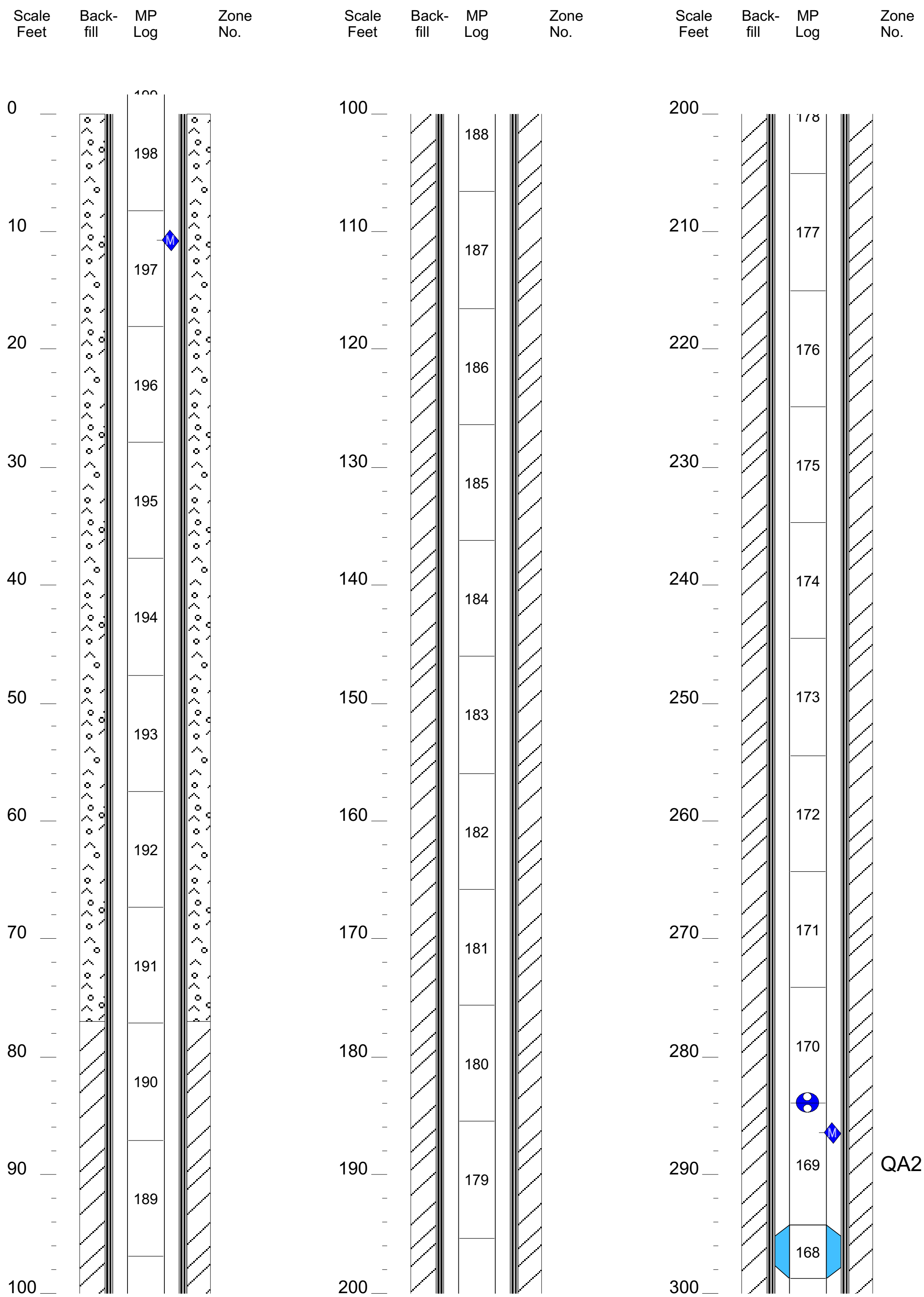
Legend

(Qty) MP Components **Geology** **Backfill/Casing**



Summary MP Casing Log
LANL

Job No: WB777
Well: CdV15



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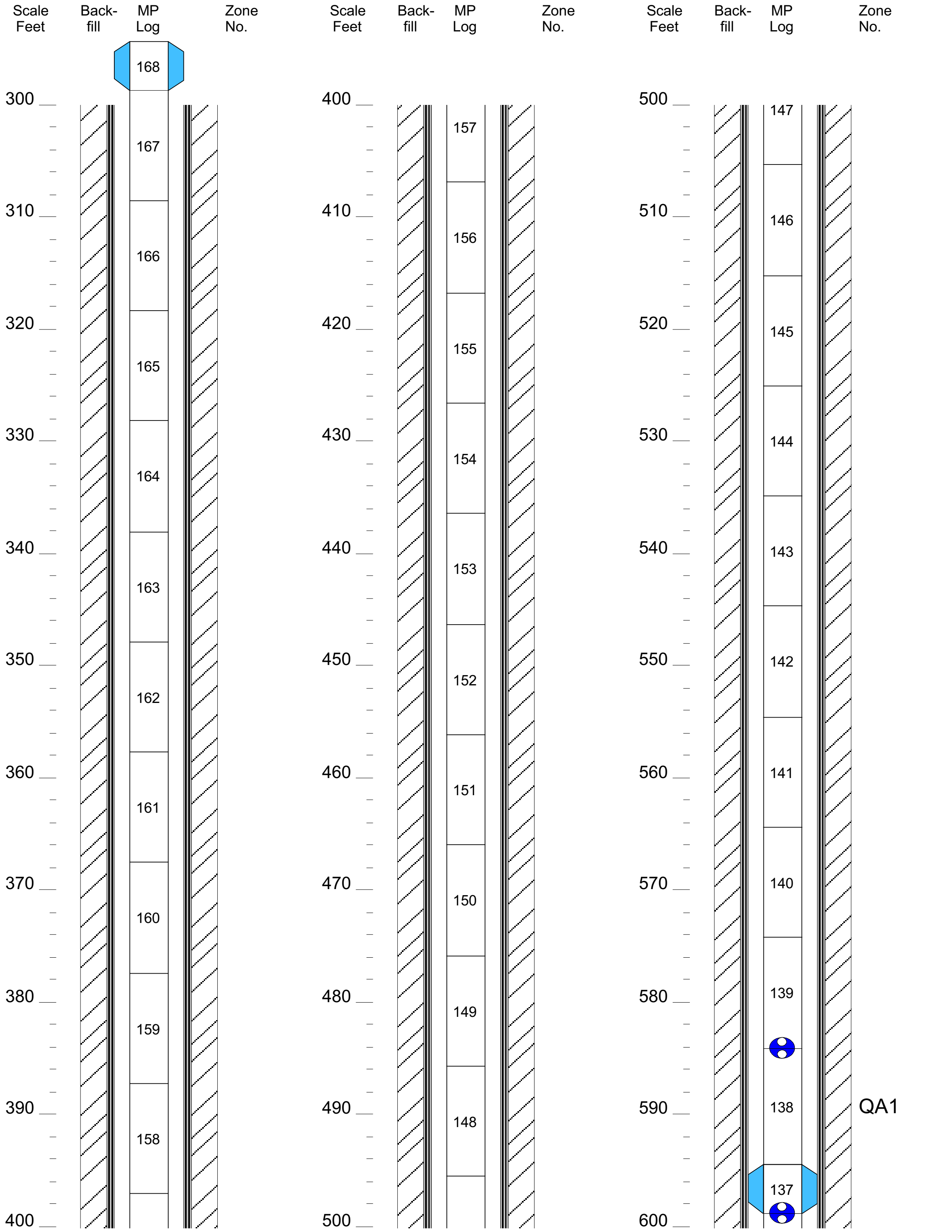
Summary MP Casing Log
LANL

Job No: WB777
Well: CdV15



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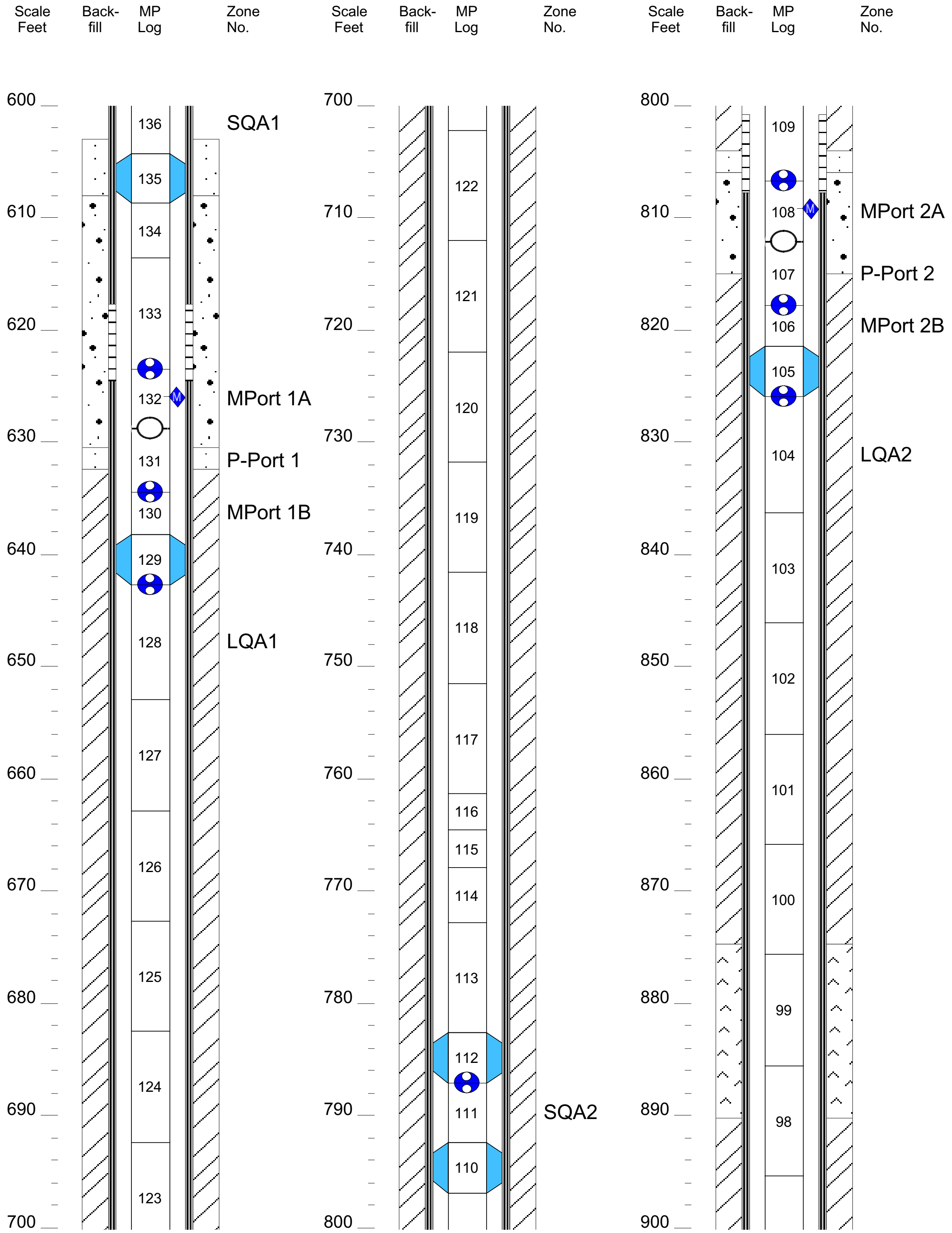
Summary MP Casing Log
LANL

Job No: WB777
Well: CdV15



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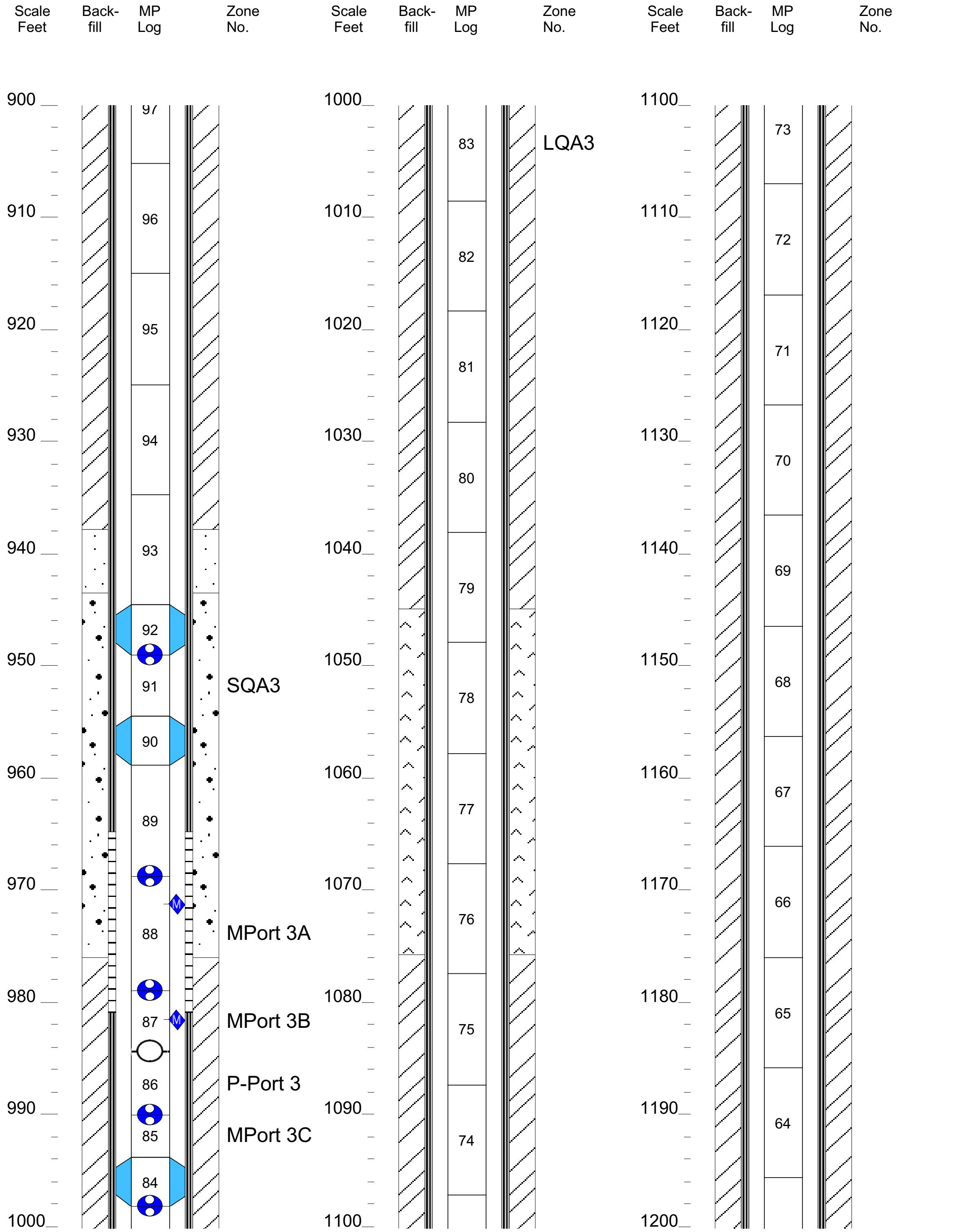
Summary MP Casing Log
LANL

Job No: WB777
Well: CdV15



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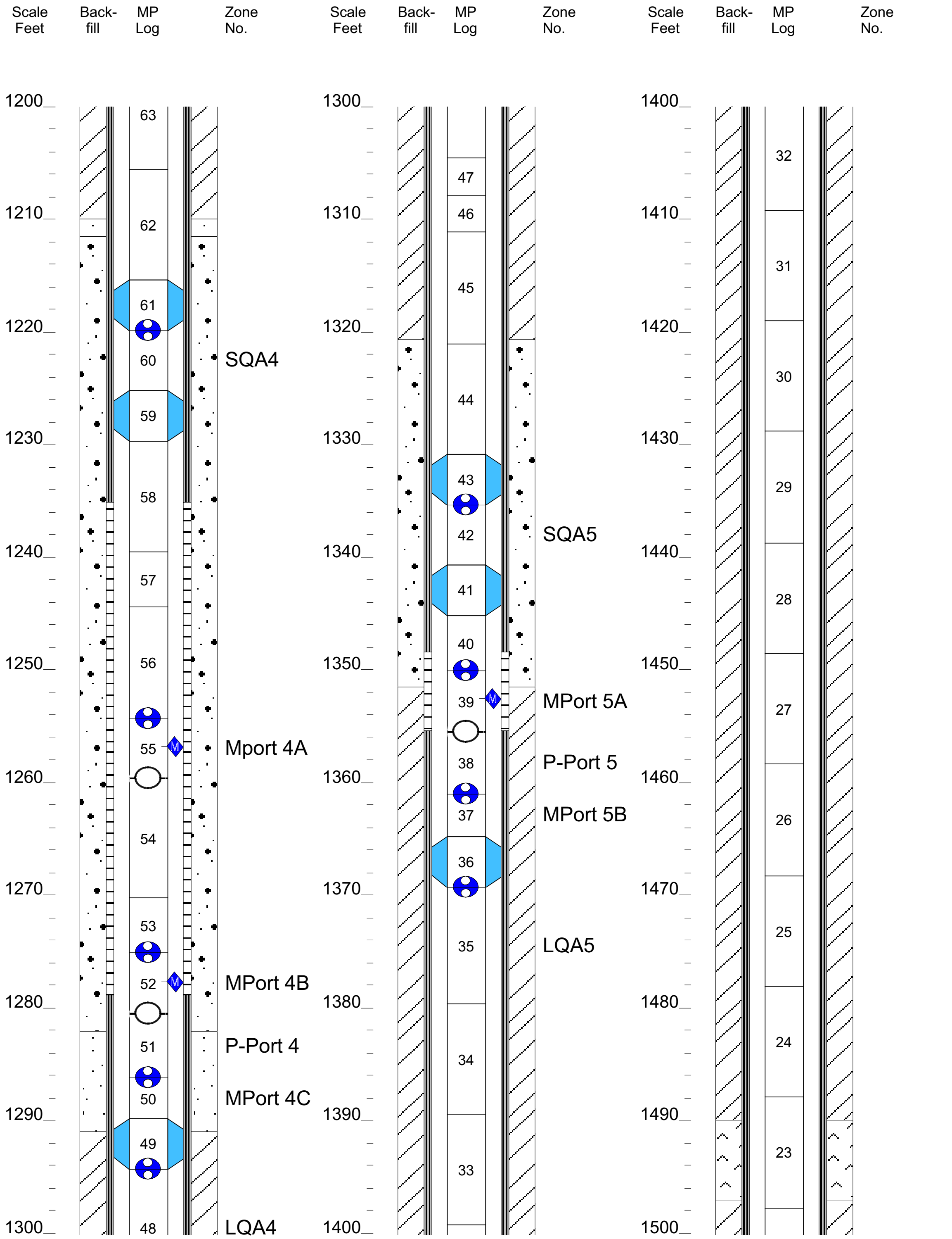
Summary MP Casing Log
LANL

Job No: WB777
Well: CdV15



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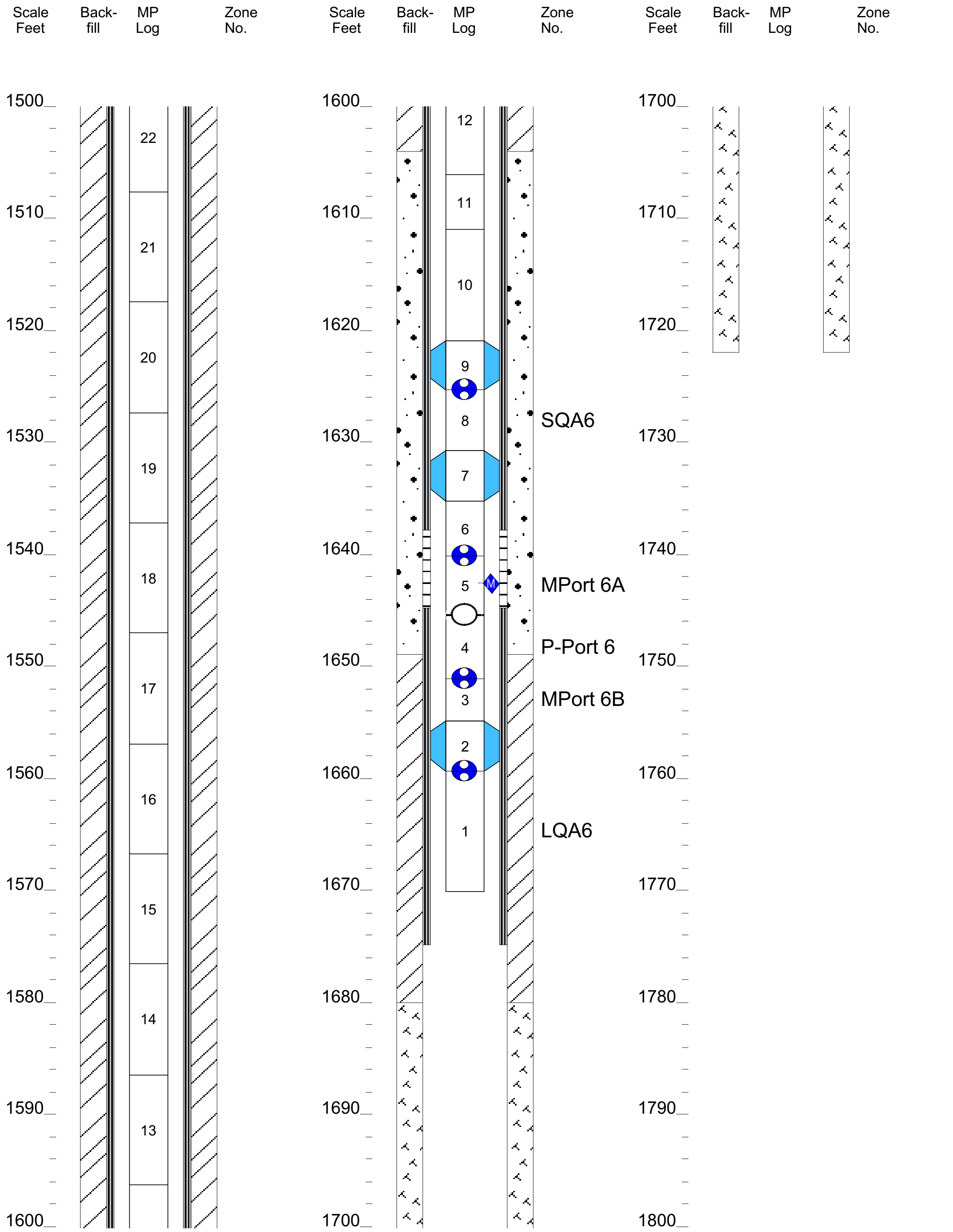
Summary MP Casing Log
LANL

Job No: WB777
Well: CdV15



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